POWER PLANT ENGINEERING

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Hetch Hetchy Water Power Development

PROJECT WILL SUPPLY SAN FRANCISCO WITH 400,000,000 GAL. WATER PER DAY AND DEVELOP 250,000 HP. BY A. W. COPLEY*

BRINGING FOUR HUNDRED million gallons of water per day over a distance of 200 mi. and down from a height of some 5000 ft., at the same time making this water do the work of 250,000 hp., sounds more like an Arabian Nights tale than an actual fact, yet a project of this kind is actually under way in California. Civilization strangely alters our mode of living and our wants. We used to be perfectly satisfied to go to a well and by main muscular effort haul up a bucket of water. Today we are no longer satisfied to go to the well; instead, we expect the water to jump down from the top of a mountain a couple of hundred miles away and at the same time furnish us with power to cook our food and illuminate our homes. It seems as if we were too easily satisfied at one time.

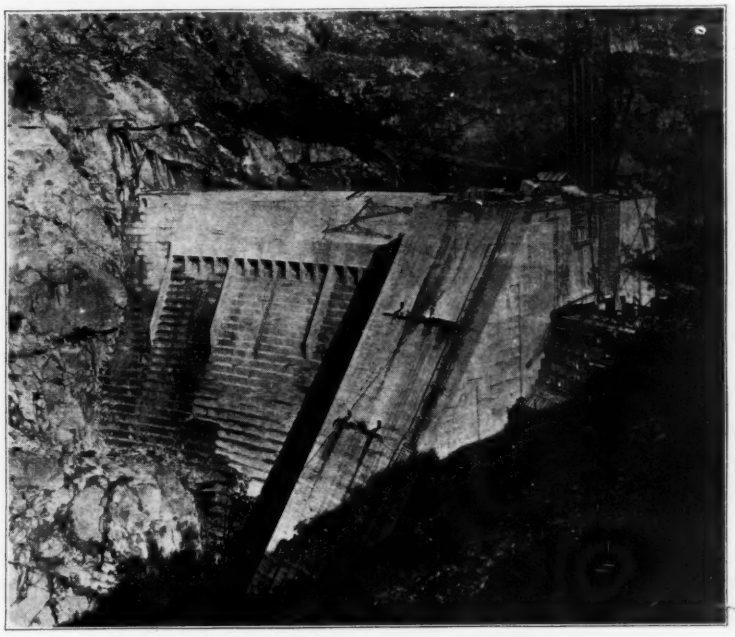


FIG. 1. GENERAL VIEW OF HETCH HETCHY DAM, DOWN STREAM FACE

One of the largest combined water and power developments in the United States is being carried out by the City of San Francisco, in the Hetch Hetchy Valley located in the Yosemite National Park. The development is being carried out primarily as a project for bringing water into the City of San Francisco, but as the water is being brought from a considerable elevation, advantage is being taken of the fall in order to develop hydroelectric energy.

This proposed water supply system is exceeded in magnitude only by the Catskill Water Supply Development for New York City, and the system for the supply of water to Boston. It is different from these two projects, however, in that they are simply water supply systems, whereas this also involves the development of power.

LOCATION OF THE PROJECT

HETCH HETCHY Valley is located in Yosemite National Park, about twenty miles north of the Yosemite Valley proper. In many respects it is similar to the Yosemite Valley but in general is on a smaller scale. At present it is inaccessible except by the Hetch Hetchy Railroad, which has been constructed by the city in order to carry on construction work. The title to this valley and the surrounding water shed was obtained for San Francisco by grant from the United States Government. By the terms of the Baker Bill, which passed Congress in December, 1913, 420,000 acres of the public domain were given to the City of San Francisco for this development. The issuance of $45,000,000 in bonds for the construction of the project had been authorized in 1910 by the voters of the city, and actual construction work was begun as soon as the grant from the Government was obtained.

Work on the project began with the construction of a railroad to carry materials into the valley. This railroad, known as the Hetch Hetchy Railroad, is 68 mi. long, of standard gage and passes through very rough country, with a maximum grade of 4 per cent and a maximum curvature of 30 deg. A sawmill was

*General Engineering Dept., Westinghouse Electric and Manufacturing Co.

also established in which was cut all of the lumber for the construction work on the ground.

Power Plant for Construction Purposes

At Lake Eleanor a reservoir was established by the construction of a dam 1200 ft. long and 70 ft. high, which gives a storage capacity to Lake Eleanor of about 8,000,000,000 gal. of water. This storage reservoir was utilized for the operation of a construction power house. Water is taken down Cherry Creek from the reservoir, led through a conduit 3.3 mi. long, consisting of 1.2 mi. of open ditch, one mile of flume and one mile of tunnel to Early Intake. Here, a head of 345 ft. to the Tuolumne River made possible a small power development which is being used in the construction of the dam and other work at Hetch Hetchy.

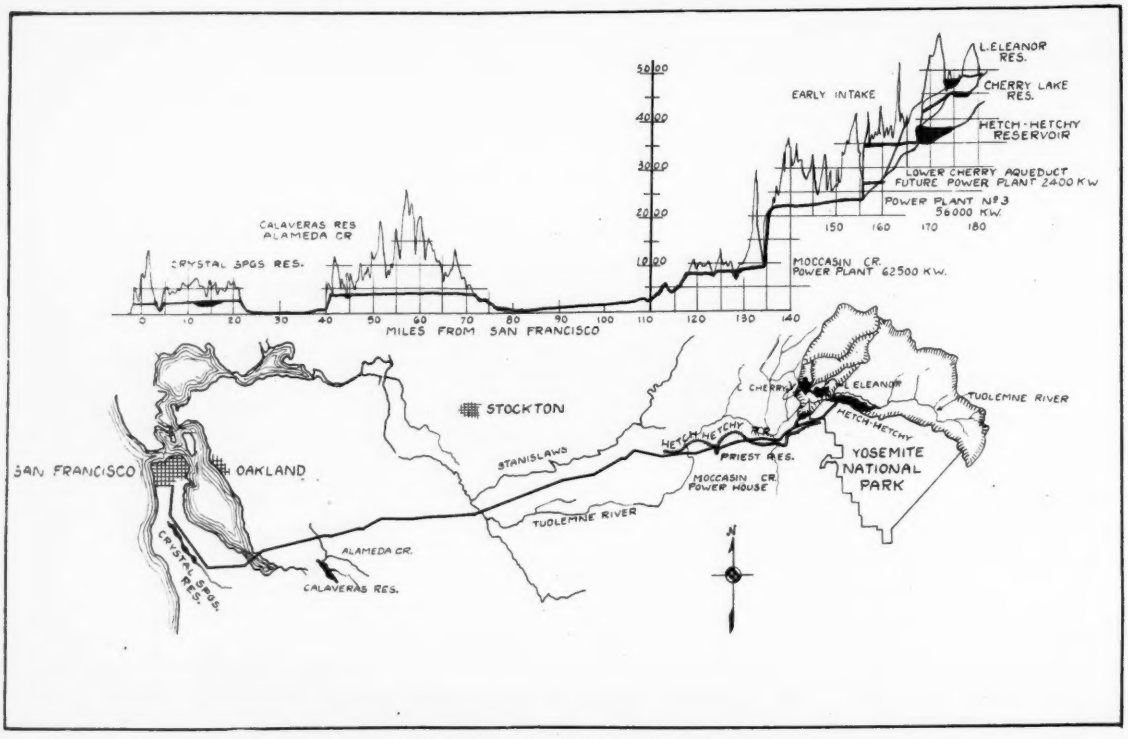


FIG. 2. MAP AND PROFILE OF THE HETCH HETCHY DEVELOPMENT.

This plant consists of three 1500-hp. Pelton Francis water wheels, direct connected to three 1000-kw., 2300-v., 3-phase, 60-cycle generators, with step-up transformers to 22,000 v. At construction points, this voltage is stepped down to 440 v. for power and 110/220 for lighting.

Development of Hetch Hetchy Valley

At the Hetch Hetchy Valley the dam will eventually be 312 ft. above the stream bed and 850 ft. long on the crest. Initially, however, it is built to only 226 ft. above the stream bed and will store 67,000,000,000 gal. of water. The ultimate capacity will be 112,000,000,000 gal. of water.

Construction of the dam across the lower end of the valley will provide a water storage over the entire floor of the valley, turning it into a lake 7 mi. long and about 300 ft. deep. This will not in any way mar the beauty of the precipitous sides of the canyon and the many water falls dropping into it, but will on the other hand enhance it. It is estimated that eventually 400,000,000 gal. of water daily can be brought from here to the people of San Francisco and vicinity and that about 250,000 hp. will be developed at the same time. As the present supply to San Francisco is about 40,000,000 gal. of water per day, it is readily seen that the need for the full capacity of the Hetch Hetchy Development will not arise for many years to come.

Water from the reservoir formed by the dam initially will flow down the bed of the Tuolumne River a distance of 12 mi. to Early Intake. Eventually the water will be taken to Early Intake from the dam through flumes and tunnels so as to permit a power development at that point which will develop 42,000 kw. at a head of about 1300 ft. The present Early Intake construction plant will be replaced by a plant a mile or two back from the present power house where the drop in head of water from the Lake Eleanor reservoir can be made about 2000 ft. instead of the present 345 ft. The plant will then develop 24,000 kw. and is known as the North Mountain Plant. The immediate development at Early Intake, however, is a diversion dam in the Tuolumne River which will turn the water into the aqueduct below this point, now under construction, to carry it to the power development to Moccasin Creek. This aqueduct consists of a tunnel 18.3 mi. long and 10 ft. in diameter, terminating at the west end at Priest Reservoir, which has a capacity of 2500 acre feet.

From the Priest Reservoir, which acts as a forebay for the power house, the water will be taken through a concrete lined pressure tunnel 5900 ft. long and 13 ft. in diameter, into the two steel pressure pipe lines, each

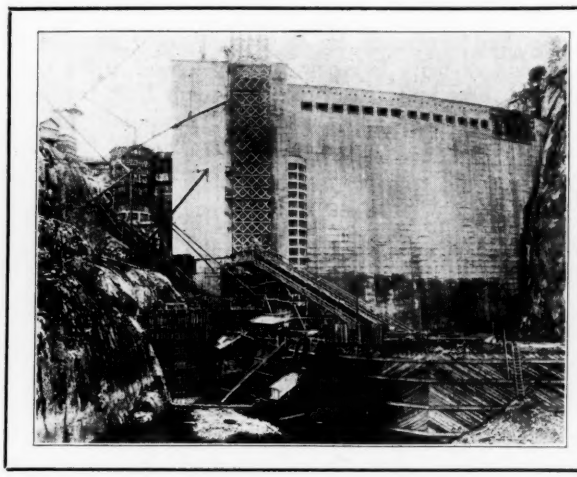


FIG. 3. HETCH HETCHY DAM, UPSTREAM FACE

FIG. 4. VIEW SHOWING CONSTRUCTION OF PRIEST DAM, FORMING THE FOREBAY RESERVOIR ABOVE MOCCASIN CREEK POWER HOUSE

of which branches into two smaller pressure pipes, which deliver the water to the water wheels at the Moccasin Creek power house. There is a static head on the plant of 1315 ft. and an effective head of 1250 ft. After the water has passed through the wheels, it will be taken through the tunnels and pipe lines a distance of 134 mi. into San Francisco, the flow being by gravity. The power generated will also be brought into San Francisco over high tension transmission lines. The water development below Moccasin Creek power plant will not be carried out immediately, and the water from the power house will be turned into the Tuolumne River for the present, as the water needs of the city can be supplied for some years without the Hetch Hetchy water. The initial development, therefore, as now being carried out, is as power development whose generated energy will allow an immediate income from the property, and which serves to hold the water rights until such times as the city's demand increases to such a point that the water is required there.

In order to care for the water needs of the city in the immediate future, a section of the final aqueduct close to San Francisco is being constructed, which will take water for the present from Alameda Creek, a distance of 23 mi., to the Crystal Springs Reservoir of the Spring Valley Water Co., now supplying the city with water. This section of the aqueduct will be rented to the Spring Valley Water Co. until the aqueduct from Moccasin Creek power house is carried along to connect with it.

Details of Moccasin Creek Power House

At Moccasin Creek power house the initial installation consists of four 25,000-hp. hydroelectric generating units and thirteen 6667-kv.a. transformers and switching equipment to supply the electric power generated to two transmission lines. The average water quantity available is 620 cu. ft. per second, with a maximum available of 1240 cu. ft. per sec. Ultimately there will be six 25,000-hp. units installed in this power house.

There will never be enough water to give a 24-hr. use of the six units but as there are no forebay capac-

FIG. 5. PROPOSED MOCCASIN CREEK POWER HOUSE

ities for the plants at Early Intake and North Mountain, it will be necessary to pass the maximum flow through them continuously and take the variation of load on the Moccasin Creek Plant, which will then be operated on a load factor of about 50 per cent. In the morning the Priest Reservoir will be full and water can be taken through the generators at Moccasin Creek as required by the peak loads up to the full capacity of the six units. By night, when the load valley occurs,

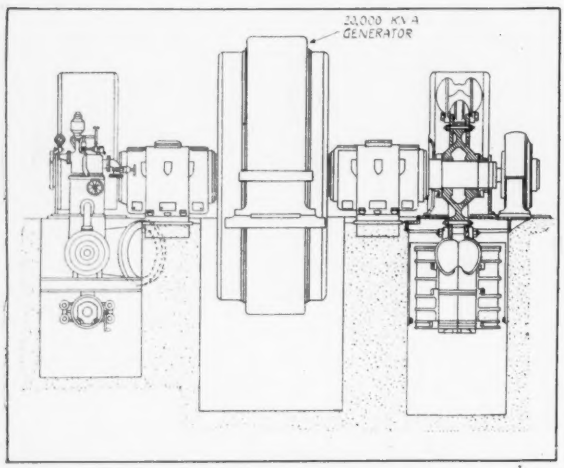


FIG. 6. FRONT ELEVATION OF ONE OF THE 25,000-HP. UNITS AT MOCCASIN CREEK POWER HOUSE

the Priest Reservoir will be empty and the plant will be entirely shut down. There will also be a storage reservoir below the plant which will provide for the uniform flow of water through the pipe line to San Francisco in spite of the non-uniform flow through the wheels of the plant.

Water Wheel Details

Each hydro-electric unit consists of a horizontal shaft generator with an impulse wheel overhung on each end, and a direct connected exciter on one end. The water wheels, manufactured by the Pelton Water Wheel Co., are of the impulse type, double overhung, with single nozzle and auxiliary relief nozzle. Water flows from the pressure pipes, through 36-in. hydraulic cylinder operated gate valves, manufactured by the Coffin Valve Co., of Boston, into the wheels.

All machine foundations are of reinforced concrete, with cast iron sole plates for the generators and the bearing pedestals. The rating of each unit is 25,000 hp. at an effective head of 1250 ft., but the wheels will have a 10 per cent over capacity margin, or a maximum rating of 27,500 hp. for regulation purposes. The shaft is of nickel steel, hollow bored throughout its length, with 8-in. diameter holes and heat treated. It runs in 22-in. ring-oiling self-alining babbit bearings which are self-cooling but which are provided with water-cooling coils for emergency operation. This water-cooling provision will allow the operation of the bearings in case foreign matter gets into the oil, or any other condition occurs to start heating in the bearings. In such cases the water cooling will be used until the arrival of a convenient time for shutting down the unit and repairing the defect.

This is strictly an emergency arrangement as provision has been made for oil storage under pressure of sufficient capacity to renew entirely the oil in the bearings of three units. Old oil can be run from the bearings into a sump and the new oil immediately introduced from the storage reservoir. The oil from the sump is then filtered and pumped to the reservoir to be used over again.

Oil pressure of 250 lb. per sq. in. is provided for the bearings for starting up the units with a minimum of fricion.

In Fig. 8 is shown a view of one of the water wheel runners. This runner is pressed on the end of the shaft and consists of a cast steel hub with two rolled nickel steel disk rings mounted on it, to carry the annealed cast steel ellipsoidal buckets of the Pelton patented chain type. A detailed view of a bucket is shown in Fig. 10. The forward lug of each bucket fits between the two disk rings and the two rear lugs are a close binding fit on the outside of the rings. One bolt passes through the back lugs of one bucket, the two

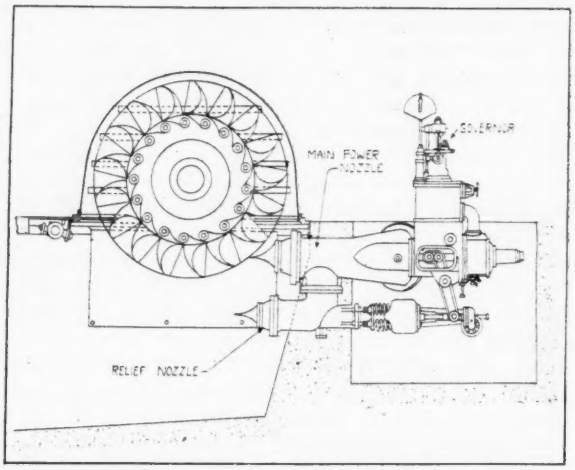


FIG. 7. SIDE ELEVATION OF 25,000-HP. PELTON WHEEL

nickel steel rings and the forward lug of the next bucket, thus making a complete interlocking bucket chain.

For each runner three nozzles are provided, one being the main power nozzle, the second the relief nozzle, placed in the same vertical plane as the power nozzle but located sufficiently below it to discharge clear of the water wheel; and the third, the braking nozzle, which is a small nozzle arranged to direct water against the rear of the buckets in order to bring the wheel quickly to rest. The main and relief nozzles are controlled by the governor, or in emergencies may be controlled by hand while the braking nozzle is hand controlled only. The power nozzles are made of annealed cast steel. The nozzle bodies are made with horizontal elbow turns, gradully tapering from their inlet ends to their discharge openings, in order to produce gradual acceleration of the water from the point of entrance to the point of discharge with a minimum hydraulic loss. An annealed cast steel nozzle tip is bolted to the nozzle body by means of a ring flange to permit ready and inexpensive renewals and is provided with a renewable forged steel seat ring at the point of maximum wear where the needle seats, so that seat renewals

may be made without the renewal of the piston and needle. The portion of the power nozzle body through which the needle stem passes for connecting to the servomotor is provided with an easily renewed extra long bronze bushed bearing sleeve, and the opening in the nozzle body is of such size as to permit the entire needle and stem being withdrawn from the nozzle body from the rear, making it unnecessary to enter the wheel pit or dismantle or remove any of the water wheel buckets, or to shift the shaft from its bearings when making needle renewals.

Power for actuating the relief needle mechanism is obtained by means of a direct mechanical connection with the power needle, the servomotor of which is of sufficient capacity to accomplish this purpose. The mechanism is adjustable so as to prevent the pressure

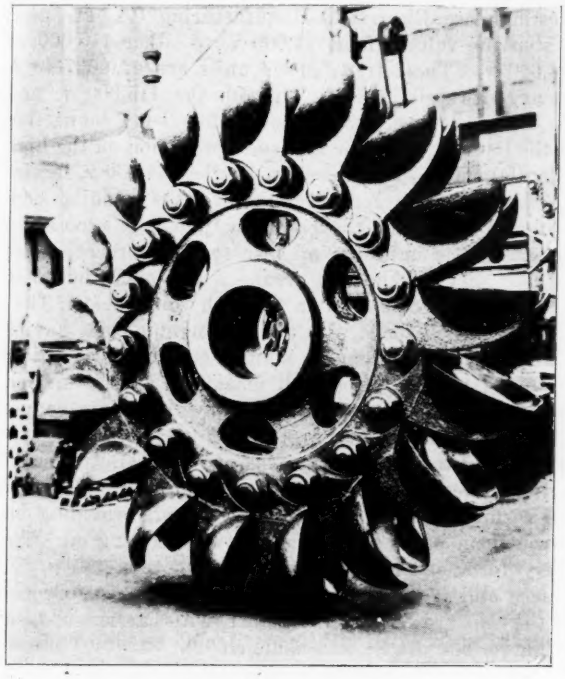


FIG. 8. WATER WHEEL RUNNER WITH PELTON CHAIN TYPE BUCKETS

rising in the penstock or pipeline in excess of 15 per cent above the static head with any decrease of load upon the wheel unit up to its maximum capacity. A relay dashpot is provided with valve adjustments which can be set to give a variable rate of opening movement of the relief needle throughout any single stroke to prevent the arresting of the velocity of the water flow within the pipeline or penstock at times of sudden load decrease, except that which is controlled by a slow closing adjustment which allows the rate of closure to be regulated to provide maximum water economy within safe limits.

This dashpot may be so adjusted as to permit the governor to move the power needle back and forth as required for speed control, under ordinary load changes, without causing the relief needle to open at all. Such an arrangement allows maximum water economy, as no water is wasted through the relief needle whatever during changes of load, whose magnitude is insufficient to cause dangerous pressure fluctuations in the pipeline. The relief nozzle can also be set to act as a synchronous bypass so as to provide for a uniform velocity of water in the pipeline.

As may be noted from Figs. 7 and 9, the general construction of the relief nozzle, with its needle and

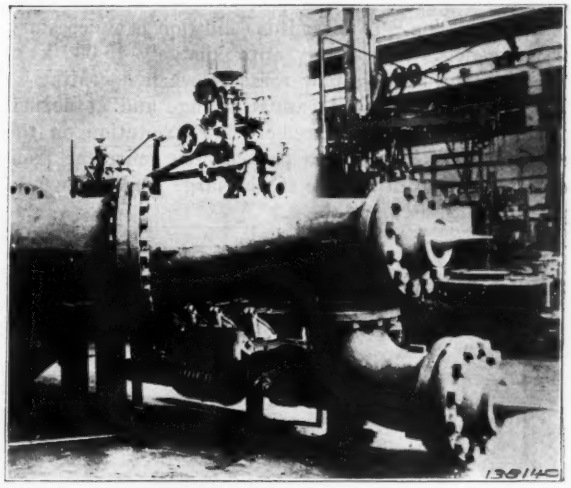


FIG. 9. POWER AND RELIEF NOZZLES AND GOVERNOR OF PELTON WATER WHEEL

nozzle tip and other mechanical details, is the same as used in the power nozzle.

Speed Control of Units

Speed control of the water wheel units is automatically accomplished by means of a Pelton self-contained enclosed direct motion governor of the oil pressure type, one of which is furnished for each main and auxiliary needle nozzle. The governor consists essentially of an actuator mounted directly on the cast-iron yoke or spacer piece, and a servomotor mounted directly in the rear of the main power nozzle to which it is rigidly connected. The actuator has a centrifugal element of the enclosed type, mounted upon a vertical spindle and driven by belt directly from the main water wheel shaft. The entire governor, as well as the servomotors and all presure gage connections, are designed for safe operation with an oil pressure up to 200 lb. per sq. in. It is possible to change from governor control to hand control, or vice versa, by a single operation of a lever which connects to the switch valve mechanism, self-contained, within the actuator base. The governor-operating valve is fitted with an adjustable load limit device, a load adjusting device to determine the division of load units and a shut-down device, all electrically operated and arranged to be controlled from the switchboard.

A central oil pressure system is used for operating the nozzles, but there is also provided a special gear pump for each of the two nozzle mechanisms for the unit, which will allow an independent hand operation of the nozzles, entirely separate from the main central oil pressure system.

The Generation Units

Generating units are of the horizontal shaft type, at 20,000 kv.a. capacity at 87½ per cent power factor, 11,000 v., 257 r.p.m., 60 cycles. A unique feature of

these units is the extension of the shaft through one of the overhung water wheels and the bolting on of a direct connected 250-v. exciter to this shaft extension.

Provision has been made in the regulating equipment for the generators automatically to take care of the line-charging conditions which may be met in case one generator alone is connected to a 140-mi., 154,000-v. transmission line. To meet this condition it is necessary for the generator to supply approximately 15,000 kv.a. at 0 per cent leading power factor when operating at 87 per cent of normal terminal voltage and at normal speed. This requires extremely low excitation on the generator field in order to prevent the generator from becoming self-exciting due to the large leading current

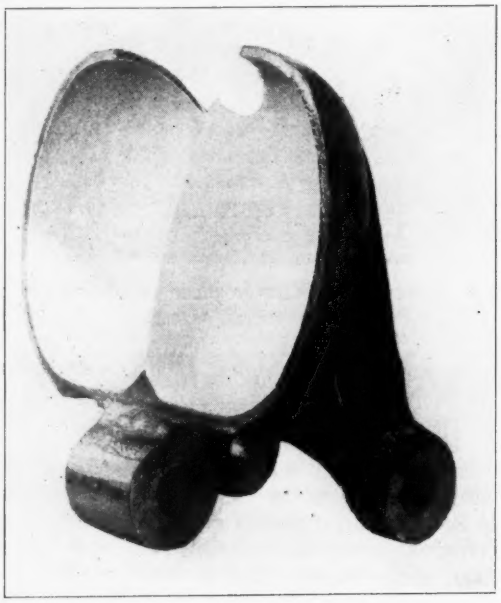


FIG. 10. CHAIN TYPE BUCKET

in the armature. The voltage across the generator field must be reduced to a value considerably below the residual voltage of the exciter, and in order to accomplish this automatically, an extended broad range regulator of Westinghouse design is used. This operates as a standard broad range regulator during normal load conditions, and on light load conditions until the load is so reduced as to require the exciter voltage to be brought to a value approaching residual. Then a faceplate rheostatic type regulator operating directly on the generator field rheostat takes control and cuts resistance into the generator field as required to keep the terminal voltage and the line voltage within reasonable limits. As the load picks up and a higher voltage is required across the generator field, the rheostatic type regulator cuts out the field resistance and the regular broad range regulator again takes control. This operation is entirely automatic both in cutting in and cutting out the resistance in the generator field rheostat.

There is also provided with the regulator a short circuit protective device which operates in case of severe short circuit conditions to reduce the voltage of the exciter to such a value that when the circuit breaker opens automatically and relieves the short circuit, the voltage of the generator will not jump to an excessively high value. The device is operated primarily by the generator voltage. When this falls, due to a short circuit, a low voltage relay operates to transfer the control of the main voltage regulator relays to a second control element, which tends to hold a constant exciter voltage whose value is just sufficient to allow the generator to give a little more than full voltage under no-load conditions. As soon as the breaker opens and the fault is disconnected, the generator voltage will, therefore, rise only to a limited value, and as soon as it approaches normal voltage the low voltage relay will reset and turn the control over to the main control element of the voltage regulator.

Details of Transformer Installation

Thirteen single-phase transformers, making three banks and one spare unit, all manufactured by the Westinghouse Electric & Manufacturing Co., are used to step the voltage from 11,000 v. to either 115,000 or 154,000 v. These transformer units are of 6667 kv.a. rating with full capacity on both the 115,000 v. and 154,000 v. connections, arranged for delta connection on the low potential side and star connection on the high potential side. The connection for the 154,000 v. service makes use of the complete high voltage winding connected in series, and the 115,000 v. potential is obtained by taps. The units are oil insulated, water cooled for outdoor service, and are arranged for operation with solidly grounded neutral on the high voltage side. They are of the shell form, with flat rectangular coils, having insulation graded from the neutral end, which is solidly grounded to the case, to full insulation at the line terminal. Each coil is wound with layers of bare copper ribbon, with but one turn per layer, so that the voltage stresses between adjacent turns are low. Between the individual coils, spacing strips of insulating material in the form of curves or waves are placed, providing between them paths for the easy flow of cooling oil. The wavy form of the strips allows every turn to be well braced and at the same time exposed to the oil. Groups of the coils are assembled together, with barriers of insulating sheets, angles and channels.

Since the transformer cores are of the shell form, there are no rivets or bolts passing through the iron, but they are clamped together by means of heavy cast end frames. The upper frame has lifting lugs and eye bolts for handling the transformers as a unit, and the lower frame is provided with feet so that the transformer may be set down without the use of external supports. The coils are braced against movement from the mechanical forces present during short circuit conditions by heavy boiler iron end plates, placed against the flat sides where they extend beyond the core, and these plates are held firmly against the coils by heavy tie bolts. "T" beams with heavy spreader bolts are inserted through the coil groups at top and bottom so as effectively to brace the coils against forces acting in a plane parallel to their faces. This bracing makes the transformer mechanically strong enough to stand dead short circuit with full voltage applied and maintained across its terminals.

As the transformers have graded insulation and are to be operated with solidly grounded neutral, only one high voltage terminal is supplied. This is of the condenser type, with porcelain rain shields placed over the upper end, for protection against the weather.

Switching equipment includes Westinghouse Type CO-1 circuit breakers for the 11-kv. side of the generators and the transformers. These breakers have a rupturing capacity of 26,000 amp. at 11,000 v., which is considerably above that which can be obtained with all the generators connected to one 11,000-v. bus. The unit system of operation of generator and transformers will be used and 11,000-v. bus shown on the diagram of connections is simply a transfer bus which will be used for synchronizing and for supplying power to the motor generator exciter set and station auxiliaries.

outgoing transmission lines, balanced relay protection is used which becomes plain overload protection on the remaining line after one line breaker has opened. Westinghouse Type CD and CO relays are used for this purpose.

Transmission Lines

Transmission lines for taking power into San Francisco have not yet been fully planned in detail, but there will be a two-circuit steel tower line insulated for 154,000 v. operation which will take the power directly into the San Francisco region. The conductors will be spaced

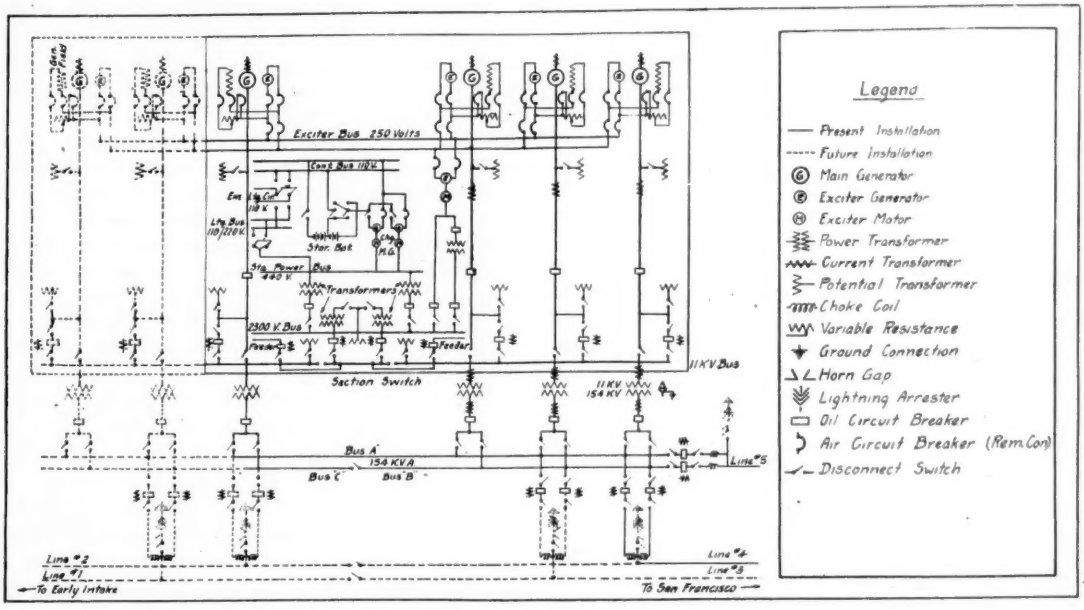


FIG. 11. SCHEMATIC WIRING DIAGRAM OF EQUIPMENT AT MOCCASIN CREEK PLANT

Breakers on the high voltage side are rated at 154,000 v. with a rupturing capacity of 2400 amp. at full voltage. They are provided with a quick break feature on the contacts, which is similar in its principle of operation to the same feature on a quick knife switch. The arcing tips are held in contact as the breaker opens until the main contacts are separated several inches and then are snapped open quickly, causing a quick rupturing of the arc. The breaker terminals are of the condenser type, with porcelain shields for outdoor service. They are duplicates of the transformer high voltage terminals.

Means for disconnecting the generator from the 11,000 v. winding of the step-up transformer, in case of internal trouble, is provided by Type CO low energy relays, differentially connected to current transformers in the main and neutral leads from the generator. These relays will open the generator oil circuit breaker and will also cut off the generator field, and operate the governor trip to shut down the unit. Differential protection for the step-up transformers is also provided by type CO relays. Additional relays are installed on the high voltage side of the transformers which operate on straight overload but are set high and have a long time element. It is intended that these relays, which are type CO, protect against a bus short circuit only, and the high settings are given them with the idea of preventing their operation on line short circuits. On the

15 ft. vertically on 90-ft. towers. The section in the San Francisco Bay district will use 345,000 circular mil copper, hemp core, conductor with a diameter of ¾ in. The section will be about 50 mi. long. The balance of the line, about 90 mi. long, will use a steel reinforced aluminum conductor of 397,500 circular mils, having a copper equivalent of 250,000 circular mils.

It is an interesting fact that the power development now being carried out at the Moccasin Creek plant just about equals the annual increase in demand for the State of California.

Habit in Location of Manufacturing Plants

Habit is the cause of location and continuance of manufacturing plants. Manufacturers wish

1. Favorable political environment
2. Desirable social conditions
3. Security of property
4. Safety to person
5. Satisfactory laws
6. Friendly public opinion
7. Pleasant relations between capital and labor—either organized or not
8. Sufficient and suitable churches, schools and places of amusement.

Robert Grimshaw.

Automatic Control of Combustion

DIRECT CONTROL IS ESSENTIAL TO SECURE THE BEST RESULTS. BY E. M. ELIOT*

THERE are three principal factors, or elements, which enter into the question of automatic control of combustion in boilers using forced draft: the air supply under the fire; the method of feeding the fuel, and the draft over the fire. These should not be confused with other operations on a boiler, such as cleaning soot, or regulating feed water, which are not part of combustion, however useful or essential they may be.

In order to obtain complete automatic combustion control, the machinery which must be governed consists of the forced draft fan supplying air under the fire, with which is included the butterfly gates in the air ducts; the stoker, or other device feeding fuel; and the damper, or induced draft fan in the boiler breeching, which controls the draft over the fire.

In choosing apparatus, one of the most important principles to keep in mind is that of direct action. If it is desired to change a condition (for instance, to restore steam pressure after it has dropped because of increased load), the most effective and immediate way to do so is to have the condition itself (in this case the steam pressure) control directly the apparatus (in this case the forced draft fan), the operation of which will most quickly accomplish the change. It is a matter of engineering experience and practice, that if a secondary action is introduced, such as, for instance, if the steam pressure controls the damper, and then the draft over the fire controls the forced draft fan, results are not as good as when the action is direct. There is more machinery to get out of order and there is more chance, both for overshooting and for lag or lead in action. It is only in Goldberg's cartoons that a fly lighting on a man's nose explodes a ton of powder 2 mi. away, by indirect action of 10 or 11 steps.

There are occasionally times when practical considerations make direct action inadvisable, but these occur about once in a hundred times. If there is any practical way of governing each of the elements of combustion by direct action, it should be accepted, even if it means using two or more sources of control.

Proof of this statement lies in an analysis of each of the three elements entering into combustion, with especial reference to the simplicity and directness, with which the machinery in each case is controlled. Manifestly that system is best which controls each element most promptly, effectively and directly, with the least amount of regulating equipment.

AIR SUPPLY

AIR SUPPLY is controlled by the forced draft fan, which in turn is driven by an engine or motor. It can thus be governed by regulators placed on the steam line to the engine, or in the electric circuit of the motor. It is possible to govern the air supply so that it will be proportional to the amount of fuel supplied, or so that a certain draft over the fire will always be carried, or so that a certain steam pressure will be maintained.

It is not a difficult matter to decide which of these three is the most important. There is no element of combustion which affects the steam pressure as quickly, or as positively, as the air supply, and steam pressure is of great importance in most plants. It follows logically, that the air supply should be arranged to give a constant steam pressure first of all. By the principle of direct action, control of the air supply should be from the steam pressure directly.

When more than one boiler takes air from a fan, it has sometimes been considered that the forced draft fan should be controlled from the steam pressure, but that the butterfly gates in the air ducts leading to individual boilers should be governed by the rate of combustion in each boiler. The fallacy of this idea would be at once apparent if boilers were as sensitive to control as electrical generators. The plan gives to the boiler what electrical men call a "runaway characteristic"; i. e., the greater the amount of combustion, the more air supply, and the still greater increase in the amount of combustion. A vicious circle is formed by which some boilers tend to take all the load, and others to drop it. This condition is made still worse if fuel feed is also dependent on draft over the fire or amount of combustion. If boilers were electrical generators, they would hunt and see-saw the load among themselves.

Usually the proper way to handle the butterfly gates in individual air ducts is to determine by a little experimenting what average setting on each boiler is best, to enable each boiler to take its share of the plant load from no load to full load. If the gates are set in that best position, and left there, each boiler will take its share of the plant load at all times, without any tendency to shift it.

It is possible to operate the forced draft fan at a constant rate, and to attach the butterfly gates to regulators controlled by the steam pressure. This gives approximately the same result as setting the butterfly gates in one position, and changing the forced draft fan through a regulator controlled by the steam pressure. Experience indicates, however, that the best method is setting the butterfly gates in one position.

DRAFT OVER THE FIRE

IN A boiler having forced draft, the damper, or induced draft fan, is the apparatus which determines the draft over the fire. The damper may be mechanically operated, in which case the regulator moves it directly by mechanical means, or it may be motor operated, in which case the regulator controls the motor circuit. Induced draft fans may be driven by engines or motors, in which case the regulator is connected to the steam line of the engine or to the circuit of the motor. The damper, or induced draft fan, may be used to maintain constant steam pressure, or it may be used to control combustion for greatest economy. The fact is, however, that steam pressure can be changed much more quickly by changing the amount of air supplied under the fire, than it can by changing the damper position, especially if the air supply (that is, the forced draft fan), is controlled directly from the steam pressure. This can be proved by actual test, and any engineer, who is skeptical

*Formerly with the Craig Damper Regulator Co. as engineer in charge of sales, now with the Wright-Austin Co.

as to the truth of this statement, should try it out in his own plant.

To make this comparative test, the pressure should be dropped when the forced draft fan is being controlled from the steam pressure by a good regulator, and the time needed to restore the correct pressure recorded. Then the pressure should be dropped the same amount as before, when the forced draft fan is governed from the draft over the fire, and the damper, or induced draft fan, is governed from steam pressure. The time needed to restore the steam pressure will be greater in the second case than it was in the first case.

Thus, the logical use for the damper is to control the economy of combustion. The case where steam pressure is maintained constant, through direct control of the forced draft fan, but the damper is also controlled from the steam pressure, is not a logical arrangement. The advantage of economical combustion, by control of the damper, is not obtained and no corresponding advantage, such as control of steam pressure, is substituted. The principal value of the damper is not obtained under this plan.

Economy of combustion is controlled by the damper by keeping the draft over the fire constant at a low figure, and direct action is obtained by governing the damper directly from the draft over the fire itself. As the amount of gases in the combustion chamber increases with increased air supply and fuel feed, the draft over the fire tends to decrease, and this decrease operates the regulator to open the damper and release the gases. This is absolutely direct action, and prompt response (measured in terms of from 2 to 5 sec.) can be obtained.

With any other form of control of the damper, such as that from the steam pressure, additional steps of action are introduced between the production of a quantity of gas and the opening of the damper to release it. Thus the damper will be opened by a change in steam pressure an appreciable length of time before the forced draft fan has increased the amount of gases to a volume corresponding to the opening. In the meantime excess air flows into the boiler and tends to reduce the economy of combustion. The same is true of steam flow, as a method of control for the damper.

In a group of boilers, direct control of each damper from the draft over the fire in the boiler to which it is attached, is a decided advantage over any form of control which governs all dampers alike, regardless of load on the individual boiler. There is no "runaway characteristic" to be considered here, as opening or closing the damper affects only the economy of the boiler, not its operation.

As a digression, the difference in principle, between control of the damper and control of forced draft fan and stoker, cannot be too strongly impressed upon the reader. One can swing the damper all day without affecting the load on the boiler, or the steam pressure, unless the damper is connected to the control of the forced draft fan or stoker (or unless the damper is shut so far that the draft will not remove the products of combustion). What is actually affected is the economy of combustion.

Change in the fuel feed or air supply affects the load which the boiler carries and the steam pressure, but does not affect the economy of combustion, if the damper is governed from the draft over the fire.

Consideration of these facts shows that the damper, and its control of furnace economy, is one matter; whereas the stoker, with its forced draft fan, controlling load and steam pressure, are another matter, and there is no excuse for mixing them. A clear understanding of this would save an immense amount of time and money, when automatic combustion control is under consideration. The economies due to automatic combustion control are almost all affected by the damper regulator, although automatic fuel feed saves something by making the feeding of fuel regular. The damper regulator saves between 5 and 15 per cent of fuel, in the average plant, whereas the automatic regulation of fuel feed and air supply, effects savings of 2 to 5 per cent. On the other hand, if constant steam pressure is important, automatic regulation of the forced draft fan and stoker will take care of this, and the damper regulator is not of value. Therefore it is not necessary to install a complete combustion control system in order to get substantial fuel savings. Installation of the damper regulator alone will accomplish this result.

There are no practical considerations to prevent direct governing of the damper from the draft over the fire. Although there are not the years of practical experience behind control of the damper, that there are back of control of the forced draft fan, there are several hundred successful installations, made under the auspices of half a dozen manufacturers, which prove the practical truth of these statements.

Fuel Feed

In the majority of plants using forced draft, fuel feed is obtained by using a mechanical stoker operated by an engine or a motor. Regulators can be applied either to the steam line supplying the engine, or to the electrical circuit of the motor.

Fuel feed can be arranged to give constant steam pressure, constant draft over the fire, or to correspond to the load demands upon the boiler. The principle of direct action would suggest governing the fuel feed from the load on the boiler, i. e., from the steam flow, especially since our previous demonstration shows constant steam pressure and constant draft over the fire to be more readily obtained by other means, than by means of the fuel feed. If fuel feed were governed from the steam flow, it would mean that more coal would be supplied to the furnace as more steam was needed.

In this case, however, there are practical difficulties to be overcome, the chief one being that flow of gases is difficult to use as a governing factor without rather expensive and delicate machinery. It is not impossible to use this form of control, and theoretically it is best, but most inventors of combustion control apparatus have used indirect action in governing fuel feed for the sake of employing simple machinery.

Indirect action does not cause as much trouble in the case of fuel feed, as it does with the other two elements of combustion, because so far it has not been found possible to make fuel feed entirely automatic. Although the damper and forced draft fan can be regulated so that frequently no human attention is necessary for several days at a time (other than oiling, etc.), this cannot by any means be said of mechanical stokers. Usually they need human attention several times a day, and since this is necessary, automatic control need not be as accurate or as complete as in the case of the other elements

of combustion. As a result of this lack of necessity for direct action, as well as because of the machinery necessary to obtain direct action, fuel feed has been, and is being, controlled from steam pressure, from the forced draft fan and from the draft over the fire, rather than from steam flow. (There is one manufacturer, however, using steam flow, notwithstanding its difficulties.)

Controlling the fuel feed from the draft over the fire has little to commend it. It means entangling the economy feature of combustion control with the operating features, which is not desirable. It also means using a sensitive form of control (damper regulators operate on pressures of 0.05 in. to 0.15 in. of water), to handle the element which determines the output of the boiler. If a damper regulator sticks, when it is controlling a damper alone, it hurts the economy of the boiler and that is all; if it sticks when it is governing the fuel feed, it may raise the steam pressure unduly, or may cause the grates to burn and load to be dropped from the boiler.

Controlling the fuel feed from the steam pressure, or from the forced draft fan, affords a reasonably satisfactory method of control. Either of these has the advantage that increase or decrease in the fuel feed is directly correlated with similar changes in the air supply, and there is less danger of improper quantities of air being supplied to the fire, than when the stoker is not linked with the forced draft fan, or governed from the same control factor.

Thus satisfactory control of fuel feed may be obtained from steam flow (if the mechanical apparatus is simple and fuel feed is correlated with the air supply in some manner), or from steam pressure, or from the forced draft fan. In actual practice, almost every form of control of fuel feed that has been devised seems to give more or less adequate service. Apparently this is due to the act that fuel feed is only semi-automatic, and human intelligence corrects the bad action of systems which are theoretically impracticable.

Regulators and Controlling Devices

It is not the purpose of this article to discuss the relative merits of particular devices for automatically controlling fuel feed, air supply and draft over the fire, but it may be well to consider some of the characteristics which such controlling devices should possess, to be most effective.

First of all, they should be as simple as possible. Boiler room crews are still composed of men who are not used to complicated mechanism, and who take care of the apparatus which they use in rather rough and vigorous fashion.

Apparatus should be strongly built for the same reasons that it should be simple. It should be capable of operation with accuracy when covered with dirt and grease, and unattended for several months, because these are practical present-day boiler room conditions. They cannot be changed over night and the manufacturer must meet them as they stand.

It should be possible to erect all controlling devices without an expert from the factory to install them; also it should be possible to take them apart and put them together again in the boiler room by following simple written instructions. The apparatus should work as well after such overhauling as it did before it.

Systems of three controls, forming a complete combustion system, should be plain to the operating engineer, so that he understands fully the function and operation of each part, and no part of the system is a mystery to him.

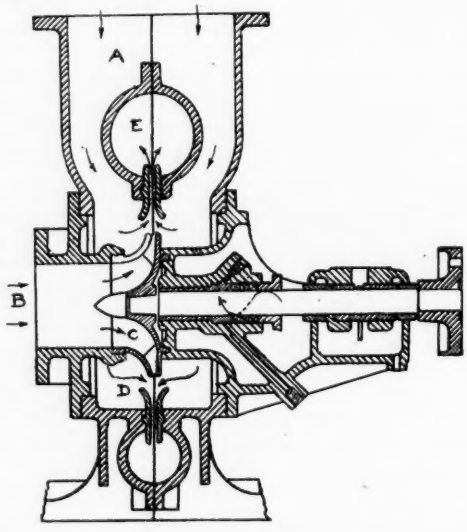
Apparatus should be sensitive enough to maintain the desired steam pressure and draft, and change the fuel feed promptly with each change of load, but it should not race, hunt or overshoot. It should be economical as to repairs required and in the use of auxiliary force, such as water, air or steam.

Each device should be as compact as possible, and piping, wiring and chains on the boiler should be reduced to the minimum consistent with good results.

To recapitulate: Steam pressure is the best control for the forced draft fan furnishing air supply. Butterfly gates in the air ducts should be set without changing. The draft over the fire is the proper control for the damper or induced draft fan. Steam flow is a possible control for fuel feed, but practical conditions today make steam pressure or the forced draft fan the best control for fuel feed. Equipment used or combustion control should be simple, accurate, compact and adapted to boiler room conditions.

Ejecteau-Air Condenser

Under this title the Navarre Cie. of Paris produces a combination water and air pump and steam condenser. The accompanying sectional drawing shows the method



COMPACT COMBINATION OF CONDENSER, WATER AND AIR PUMP

of operation. Water arriving through an impulsion turbine at B is driven upward and downward toward E and D. Air or steam arriving at A is caught and driven out at E, the steam being condensed by contact with the cold water. Acting as an air pump the makers claim that it will produce a vacuum of 746 mm. (29.375 in.) of mercury, using water at 50 deg. F. Acting as a condenser, it puts in motion 3 liters (0.8 gal.) of water per horsepower-second, and will condense 790 lb. of steam per hour when using 30 lb. of water per pound of steam. The apparatus is made in sizes to condense from 550 to 66,000 lb. of steam per hour.

Mechanical Force Made Use of to Indicate CO_2

RAPID DETERMINATION OF GAS SAMPLES IS FEATURED IN NEW INSTRUMENT WHICH DOES NOT USE CHEMICALS OR DELICATE ELECTRICAL DEVICE

PROBLEMS of recording or indicating CO_2 often involve more than the requirements of accuracy; in fact, the element of time lag between taking the sample and obtaining the reading may result in a decided handicap to the observer of operating conditions.

Engineering, of London, describes an instrument, of Continental origin, which is novel and practical in numerous ways, it is known as the Ranarex CO_2 recorder. One claim for this instrument is its ruggedness; this is based on the fact that the instrument is entirely mechanical in its action, that is, it does not require any chemicals nor does it make use of delicate electrical devices

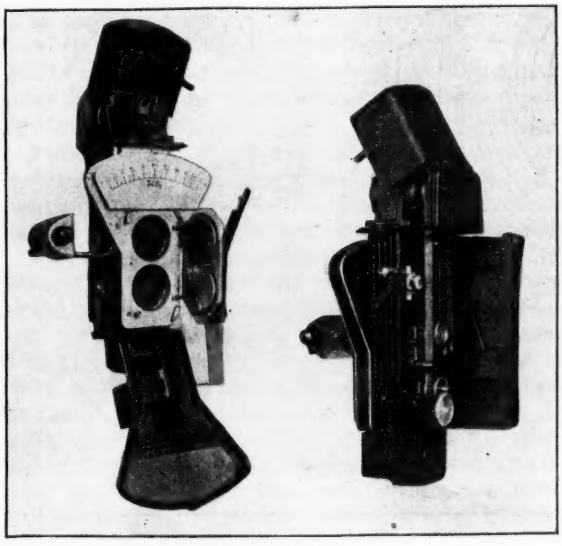


FIG. 1. PHOTOGRAPHIC VIEWS OF CO_2 INDICATOR WHICH IS ENTIRELY MECHANICAL IN ITS ACTION

such are required when the resistance of gases is measured. A further advantage claimed for this instrument is that of almost instantaneous recording; in fact, the time lag between taking the sample and recording is only from 20 to 30 sec.

General views are shown of the instrument in Fig. 1. The essential parts are two small fans which are both driven at the same high speed by means of a belt connection to the motor mounted at the top of the instrument. Each fan is mounted opposite a disk which is provided with vanes, each fan and disk are mounted in a gas tight chamber. The friction of the air or gas set in motion by the driven fan will tend to rotate the disk, and this tendency to rotate will be in proportion to the density of the gas in the chamber; it is this fact that is taken advantage of to indicate the per cent of CO_2.

Figure 2 is a line diagram of one of the gas-tight chambers in which is contained a driven fan and a disk with vanes. The driven fan is duplex in construction; that is, the right-hand side I draws gas in through inlet 4 and expels the gas through outlet 5, while the left-hand side 2 of the impellor gives a whirling motion to the gas in the chamber. The result is a torque transmitted to the disk or recording fan 6. The magnitude of this torque will depend upon the density of the gas in the chamber, which will change with varying per cents of CO_2 and the square of the speed of the driven fan. This latter effect need not be considered, however, because the fans in both chambers are driven at the same speed.

One chamber is connected up so that it will be filled with the gases of combustion and the other chamber is

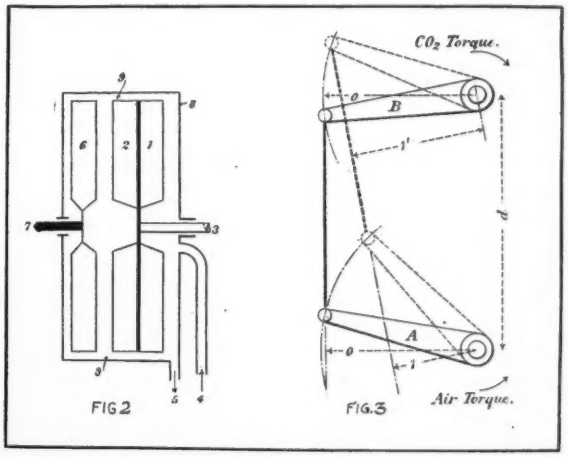


FIG. 2. SCHEMATIC DIAGRAM SHOWING RELATIVE POSITION OF DRIVEN AND RECORDING FANS IN GAS CHAMBER

FIG. 3. SKETCH SHOWING HOW LINK MOTION CONNECTS THE TWO RECORDING FANS

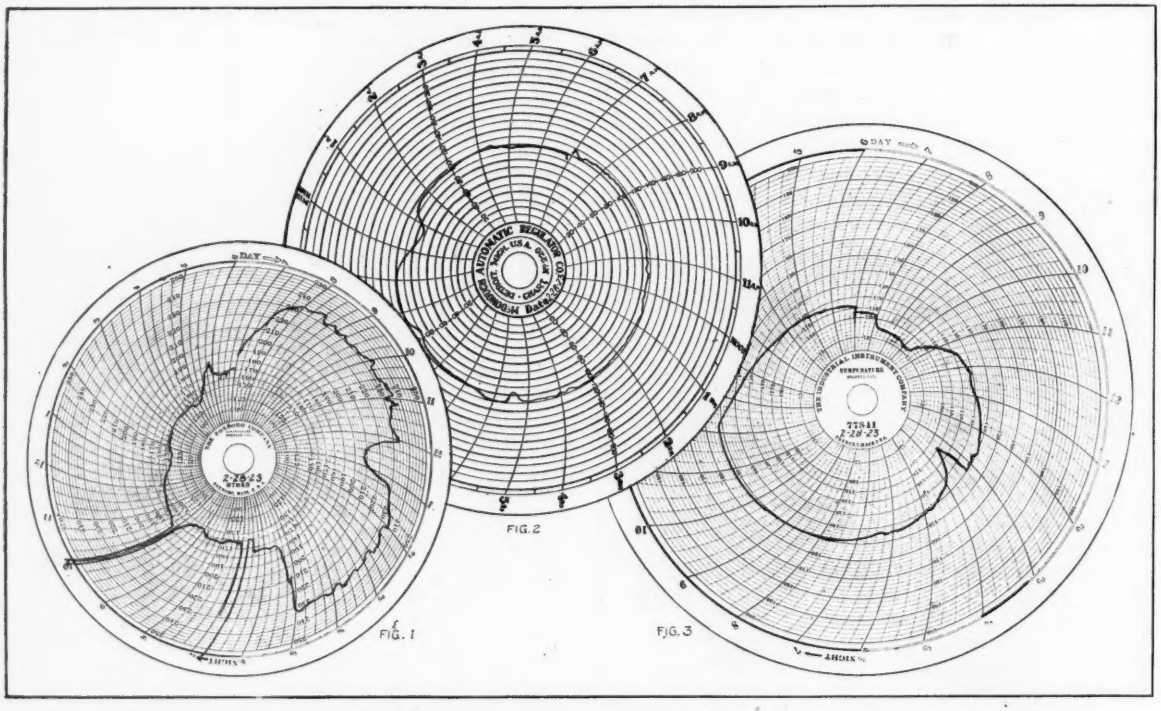
open to the atmosphere, the torque then transmitted to the disk 6 will vary with the density of the gas in one case and air in the other. The two disks 6 are coupled together through the levers A and B and a connecting link as shown in Fig. 3. The length of the connecting link is less than the distance center to center of the disks, so that the effective length of the levers A and B varies according to their respective positions. The recording mechanism is attached to the disks 6 through the lever and link motion, the torque due to air density is transmitted through lever A and the torque due to the density of the gas is transmitted through lever B. With the instrument in operation, the levers A and B will take up a position in which the torque due to air and gas density balance each other, and the indicator or recording device, as the case may be, then shows the percentage of CO_2 which has determined this position.

Rugged construction is possible, due to the comparatively large forces which actuate the indicating device, which in itself is positive in its action. In order to eliminate variables due to temperature, it is necessary to bring the temperature of the gases of combustion to the same temperature as that of the air; it is this requirement that accounts for the time lag of the instrument. It is claimed that the instrument is accurate to within one-tenth of one per cent and that this accuracy is unaffected by variations in the speed of the fans between 2500 and 3500 r.p.m. The power required by the motor is approximately 40 w. A check on the instrument may be made at any time by running both chambers filled with pure air, under which conditions a zero reading should be obtained.

Graphic Charts Tell Interesting Stories

EACH CROOK AND TURN IN THE GRAPHIC RECORD IS LIKE A WRITTEN WORD TO THE MAN WHO KNOWS HIS PLANT. BY FRED S. RUTLEDGE

IT MAY be part of the daily grind in the power plant to analyze the records of the plant but it is probably the most interesting and profitable work that the engineer has to do as the facts brought out are seldom twice alike and it is absolutely essential if one wishes to secure fuel economy comparable to the best modern practice. It is with the intention of pointing out how certain charts may be used to indicate operating conditions that the accompanying graphic records are reproduced here.



THESE CHARTS SUGGEST NEEDED REPAIRS, NEGLECT OF DUTY, AND HEAT LOSS DUE TO OPEN DOOR

Fig. 1. Record of feed water temperature. Fig. 2. Variations in boiler pressure during 24-hr. run. Fig. 3. Temperature of dry kiln.

These charts tell several things that otherwise would go on for some time before detection and also furnish indisputable evidence of certain events that happened outside of my jurisdiction, but for which my department used to get the blame, until the instruments and records showed where the fault lay without a doubt or argument.

Considering Fig. 1, which is a chart taken from a recording thermometer showing the temperature of the boiler feed water, it will be noted that the instrument started recording at 7 a. m., after the main engine had been running about 15 min. The temperature of the feed water rose gradually until at 8 a. m. it reached 234 deg. F. and the back pressure valve opened, at 8:30 the temperature reached 236 deg. F. when the back pressure valve opened again, and so kept on rising and falling until at 10:45 a. m. there was an almost vertical drop of 6 deg. This, I have my suspicions, was caused by the fireman increasing the rate of feed much beyond the usual amount and then shutting it down until about 11:07 when the temperature takes another drop and goes down to 229 deg. at 11:35 a. m. At this point he came after me on the run saying that No. 2 boiler was going dry and he could not raise any water, which at that time was out of sight in the glass.

High and low water alarms are mounted on top of the boilers and are operated by means of a float and lever mechanism working two valves. The high alarm was blowing but sounded rather funny and upon investigation was found to be blowing more water than steam. No water came when the gage cocks were opened and trying the valve on the blowdown from the water column it was found to be a half turn open. When water gets high enough so that it comes out of the high-low alarm, it is within 4 in. of the top of the shell, so we shut the valve on column blowoff and blew boiler down to normal water level.

At 12 load went off, all except lights, elevator service and motor driven air compressor for 30 min.; then the temperature started to come up until it got above 230 deg. F. where it remained with slight variations until 5 p. m., when the main engine was shut down and boilers blown and given a charge of boiler compound. This takes about 30 min., from 5:30 p. m. till about 6:27 p. m. when the pump was started and ran till 6:45 p. m. then the temperature raised until the pen ran clear off the chart. This means that the pump was shut down, feed valve on the branch lines to the boilers left open

and the check valves leaked, letting the water from boiler back up into pump line and the pump valves leaking too let the boiler pressure work back through the pump and connections into the heater. As soon as the pump was started the pen came back to 162 deg. F. from which point it varied but slightly until 10 p. m., when the same condition occurred again. This leaking was remedied the following night, by repairing checks and grinding valve seats in the pump and putting in new valves.

There is a trap to drain the water from the receiver separator of the main engine and occasionally this gets to leaking. The discharge from the trap goes into heater about 3 ft. below the water level and the temperature of feed water as shown during the night indicates when trap is blowing through. We can also tell when there is a leak in the heating system, if it is enough to affect the vacuum on the return line.

In the summer time, from June 1 to Oct. 1, boilers are used very little, only one being used at a time and not often fired more than 8 hr. out of the 24, the steam being used for dry kilns. If the thermometer stays in the vicinity of 200 deg. F. when the dry kilns are on it usually denotes that one or more of the thermostatic valves on return line of coils are out of order and blowing steam through.

There are also stories told by the chart in Fig. 2 which is from a recording steam pressure gage. The slight variations in the line from 7 a. m. to 5 p. m. were caused by hand firing old lumber and scrap that came from an old building they were tearing down. The drop between 5 p. m. and 5:30 was caused by shutting down the fan engine and stokers, blowing down boilers and feeding compound. At 8:45 p. m. the fire was cleaned. From 11 p. m. to 12:30 a. m. the fireman fell asleep. At 4:30 a. m. fire was cleaned again and so ends the story of one day.

Figure 3 is from a thermometer showing the temperature of the dry kilns used for drying painted articles. Before this thermometer was installed there was lots of trouble caused by the products placed in these kilns not getting dry. Each kiln has a valve on the line to its coil and as soon as the kiln is shut up, the attendant is supposed to open the valve. Sometimes he did and sometimes he didn't, with the result that goods were ruined. After the evidence was down in white and red, the valves were always opened. The charts shows that steam was turned on at 10:30 a. m. At 3:15 p. m. the kiln door was open for 15 min. but steam was not shut off. At 12:30 a. m. the goods being properly dried, steam was shut off by the attendant, but the kiln not opened. This thermometer has saved thousands of dollars worth of goods, as they can be spoiled in three ways:

1. By not turning steam on at all and letting the kiln stand cold; 2. Steam not on long enough, leaving goods sticky; 3. Steam on too long, changing the color of certain kinds of paint.

By means of the feed water chart an engineer can keep a check on the boiler feed pump, piping, valves and fittings. He can tell when stop valves on branch feed lines are leaking and keep a fair check on whether the night man is feeding water fairly even or not, when the heating system is turned on. How he can tell whether the night man is tending to business or not, when the heating system is on, is by the variation in temperature. If he pumps the boilers full and then shuts the pump off and lets the water go down, it shows up, by the water cooling off when pumping fast and coming up when the pump is running slow or shut down. If it is watched, the returns are almost enough to supply the boilers and when the whole 15,000 sq. ft. of radiation is on, with stoker fan engine vacuum pump and boiler feed pump running, the water stays around 190 deg. F. On the night the chart, Fig. 1, was made the weather was warm enough so that it was scarcely freezing and no steam was turned on buildings, after the dry kilns were shut down, until 4:30 a. m., when the water cooled down but began to get hotter until nearly 6 a. m. when the boilers were blown and boiler compound fed.

Besides studying these charts, we keep a record of power generated, as shown by a recording watt meter, and the amount of coal burned is kept track of by coal meters, which record the number of strokes of the stoker rams. By weighing a given amount of coal and running it through the stokers a check is obtained on the amount of coal per shot of ram. At the end of each month a condensed report is made up such as shown in accompanying table. By comparing reports, we get a good check on whether the plant is operating up to standard, improving, or slipping down hill. In comparisons between the month of February from 1918 to 1923, inclusive, these facts are noted: The amount of coal burned in February, 1923, for power was 127,180 lb. and 26,820 kw.-hr. were generated. $26{,}820 \div 0.746 = 35{,}951$ hp.-hr. Hours operated, 222. Average load per hour, 120.8 kw.

The load was

38 per cent greater than in February, 1918
21.9 per cent greater than in February, 1919
2.3 per cent greater than in February, 1920
52.2 per cent greater than in February, 1921
59.1 per cent greater than in February, 1922

While the coal consumed for the same periods was as follows:

Used in Feb., 1918, 63.8 per cent more than in Feb., 1923.
Used in Feb., 1919, 34.6 per cent more than in Feb., 1923.
Used in Feb., 1920, 30. per cent more than in Feb., 1923.
Used in Feb., 1921, 7.7 per cent less than in Feb., 1923.
Used in Feb., 1922, 16.6 per cent less than in Feb., 1923.

It may not pay to keep records, but I have always tried to improve on any previous performances and by watching the daily log I can tell almost at once when things are slipping. My log book is just an ordinary stenographer's note book in which is recorded the date, the time of starting, the meter reading at that time, the time of stopping, meter reading and the day's output in kilowatt-hours. Day and night coal consumption is kept separately by recording the total strokes of stoker counter. This multiplied by the constant which in our case is 18, equals the pounds of coal burned during the time shown. Ash, which is the amount removed during the run, is also recorded separately for the night and day shifts, but the total of coal burned and ashes removed for the period of 24 hr. also appears on the log.

Wed., Dec. 13th, 1922

7 a. m.	856750	5:00	858230	1480 kw.
Day	307 = 5526	Ash	409	Weather, cold
Night	276 = 4968	Ash	320	Lowest temperature —12°
Total	10494		729	Ash per cent, 6.9.

If any coal or supplies are received or repairing done to any machinery that is noted below, at the end of

the month it is all copied in a book for permanent record and a condensed report made out and typed in duplicate, one copy going to the general manager, the other I paste in a book, which gives a permanent record of all events in connection with my end of the plant in a shape that can leave no chance of guesswork or dispute.

Keeping these records has been the means of lowering the fuel consumption about 45 per cent and bringing up the efficiency of the plant as a whole. If a man goes at it in the right way he can make his plant a course of education that does not require a large expenditure for books or of time and likewise make the man higher up see that you take an interest in his affairs and pave the way for better jobs and larger salaries.

ENGINE ROOM MONTHLY REPORT
DEC. 31, 1922

	T.	Lb.			
Coal on hand 12-1-22	194	882	@	$7.30	$1419.41
Coal bought during month	121	1000	@	7.15	868.72
Total for month	315	1882	@	7.24*	$2288.13
Coal used during month	142	134	@	7.24	1028.56
Bal. on hand 1-1-23	173	1748	@	7.24	$1259.57
Coal used for power	68	1364	@	7.24	$497.26
Coal used nights	63	604	@	7.24	458.30
Coal used Sundays and holidays	10	166	@	7.24	73.00
					$1028.56

Power generated, 29,010 kw.-hr. × 0.746 = 38,887 hp.-hr.
Coal per kw.-hr., 4.7 lb. Coal per hp.-hr., 3.5 lb.
Cost per kw.-hr., $0.017. Cost per hp.-hr., $0.012.
Ashes removed, 31,324 lb. Ash per cent, 11.

The load dropped off about 5 per cent below last month but increased 45.1 per cent over the corresponding month a year ago and 18 T. less coal was burned in the current month than in December, 1921. No repairs or supplies.

Facts Regarding the Use of Powdered Coal

ENGINEERS INTERESTED in the use of powdered coal should find much of interest in Bulletin 217 just issued by the Bureau of Mines. This bulletin contains information regarding the preparation, transportation and combustion of powdered coal, and is published through the courtesy of the Canadian Department of Mines for whom the bulletin was originally prepared.

According to John Blizard, fuel engineer of the Department of the Interior, manufacturers and operators of the larger coal fired furnaces cannot afford to disregard the possible advantages of pulverizing their coal before burning it. In practically all cases where powdered coal has displaced hand firing, the coal consumption has been reduced considerably.

By the term powdered coal is meant coal subdivided so that it may be burned in suspension when mixed with the necessary supply of air and may be conveyed easily by means of a screw conveyor, by compressed air, or suspended in a stream of low-pressure air to the furnace.

*Average.

Since the coal has to be pulverized, it is usually better to purchase slack coal, which is usually cheaper and costs less to pulverize.

Practically all coals from lignite to antharcite, and even coke breeze have been pulverized and burned. But anthracite and coke breeze require more energy to pulverize them than softer coals, and low-volatile coals are difficult to ignite and must be burned in specially designed furnaces. One of the principal difficulties in burning powdered coal lies in the disposition of the ash; and for this reason it is desirable also to use a coal which contains little ash and that melting at a comparatively high temperature. The power used to pulverize and convey similar coals to the burner is approximately proportional to the weight of the coal pulverized, and it is clear that the pulverizing and conveying costs will, therefore, be greater per heat unit delivered the lower the calorific value of the coal.

In the modern sense a powdered-coal plant consists of apparatus which converts raw coal into powder and conveys it to the furnace, into which it is delivered as required and burned in suspension. The systems used to accomplish this may be divided into two classes: (1) The unit system, in which one machine prepares and delivers the coal to the furnace with the necessary air for combustion, and (2) the multiple system, in which the coal is prepared in one building and transported to another building wherein is situated the furnace in which the coal is to be burned.

Principal among the advantages of powdered coal firing over hand firing lie in the comparative ease of conveying coal to furnaces and in the practically complete combustion of the coal, with little excess air, in close contact with the material to be heated, thus avoiding the convection, radiation, and excess-air losses which accompany hand or stoker-fired furnaces placed outside reverberatory and many other furnaces. For this reason, the most successful field of use of pulverized coal installations has been for those purposes where they have replaced externally fired furnaces. For purposes such as steam raising, where the burning coal can give up heat directly by radiation to the boiler heating surface, there is therefore less opportunity for reducing the fuel consumption by burning powdered coal instead of burning coal on a grate, since the losses which may be reduced by substituting powdered coal firing for hand firing or stoker firing are those only which are due to incomplete combustion and using excess air. These losses, however, are not inconsiderable.

Certain drawbacks to the use of powdered coal are cited by the author of the bulletin. Before powdered-coal can compete successfully with grate firing, it is obvious that the gain due to the smaller consumption of powdered coal must offset the cost of preparing, conveying, and burning it. There is a further disadvantage with powdered coal. In grate firing, the ash is left on the grates and in the ash pit; but with powdered coal the ash is blown into the furnace, out through the stack, and with some badly designed furnaces out through openings in the furnaces. It may also form a troublesome slag, and fill up the flues so as to impede the draft.

On the whole, powdered-coal plants cannot be said to be clean. There are fairly clean powdered-coal plants; but generally, though not universally, a plant using powdered coal is dirtier than a grate-fired plant.

Types of Heaters for Hot-Blast Work---I

METHODS OF CONSTRUCTION AND ASSEMBLY ARE DESCRIBED FOR HEATING PLANTS IN PUBLIC BUILDINGS AND INDUSTRIAL PLANTS. BY CHARLES L. HUBBARD

ENGINEERS IN most large buildings, whether public institutions, schools, office buildings, or manufacturing plants, usually have something to do with hot-blast apparatus—either for ventilation, heating, drying, or a combination of these. It is proposed here to give in simple form data and suggestions which will assist the practical man in selecting a heater for a given set of conditions, and also to enable him to determine the proper relation between depth and heating surface to secure the final air temperature desired and the total heat quantity required to warm a given space. Details relating to heater arrangement, pipe connections, air venting, temperature regulation, etc., will also be touched upon, in such a way as to help the engineer in laying out a heater for a new plant, in adding to an old one, and in getting better results from one already in use.

TYPES AND CONSTRUCTION OF HEATERS

STANDARD HOT-BLAST heaters are furnished in two general types, those made up of wrought iron or steel pipe (usually one-inch) screwed into cast-iron bases, and those in which the entire section is of cast-iron. In addition to these, special heaters of small size are sometimes made up in various forms of iron pipe and regular fittings, or of sections of cast-iron indirect radiation (pin radiators, etc.,) to occupy positions where the regular forms of hot-blast heaters would not fit in to advantage. As between iron pipe and cast-iron sections, there is little choice as to the efficiency of a given amount of heating surface, and convenience and the form of the available space will usually be the deciding factors. In the design of any heater, two essential points must be considered: Positive circulation of steam through all parts of the heater; and flexibility, so that expansion strains will be taken care of without producing leaks at the joints or cracking the sections. Circulation is dependent upon air venting, and the construction must be such that the air will be forced ahead of the entering steam to some point where it can be removed by means of suitable valves, depending upon the system employed. Four common forms of pipe heaters are shown in Fig. 1, which illustrate the general principles of construction employed to secure both circulation and flexibility. In the first of these, "A," the base is divided by a transverse partition. Steam enters at the left, passes up through the loops of pipe and down to the return or drip chamber at the right, forcing the air before it. The greater part of the condensation formed in the upward passage through the pipes at the left will be carried along with the flow of steam, and fall into the return section of the base, at the right; but any water which flows back against the current of steam into the supply chamber will pass into the return side through a small opening between. Flexibility is secured by the loop form of the piping which allows for any unequal expansion when steam is first turned into the heater. The section shown in "A" is five rows of pipe deep, but this varies more or less with the size. This form of heater is confined principally to small units where temperature regulation is secured by other means than by turning on and shutting off separate sections. The form of base employed in "B" is divided differently for the flow of steam and condensation, although the loops of piping are practically the same as in "A." In the standard pattern, each base or section contains four rows of piping, as shown at the left. When assembled in a stack of two or more sections, the steam headers may form a continuous passage so that the entire heater is fed from a single connection, or they may be separated by blanks so as to divide the heater into groups of one or more sections each, as may be desired. Any condensation which flows back from the vertical pipes at the left passes through the drip opening "e" into the return

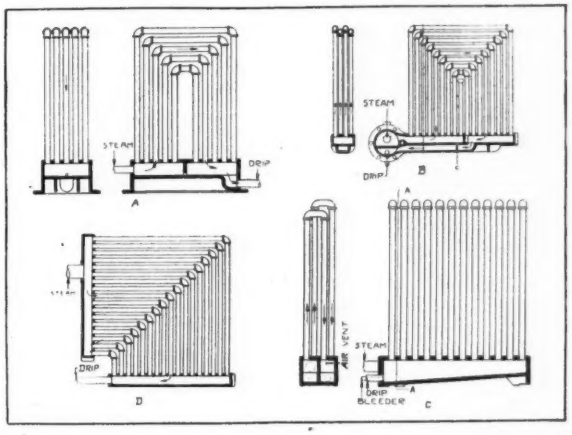


FIG. 1. FOUR COMMON FORMS OF PIPE HEATER: A AND B, LOOP TYPE; C, RETURN BEND; AND D, MITRE TYPE

passage at the bottom of the header. This is a standard form of heater and is used for all sizes of units by proper assembling.

In the "return bend" form of heater, the base is divided lengthwise, as shown in "C," and all of the pipe loops are practically the same length. Each standard section contains four rows of pipe, and has a separate supply and return connection in the assembled stack. Condensation from the supply side of the base is carried off through a bleeder connection, the pipes from each section leading to a single line connecting with a trap provided especially for this purpose and separate from that taking the general condensation from the heater. In some cases, the bleeder pipe drains back into the main return pipe through a short water seal or siphon loop. The objection to this is danger of freezing when the section is shut off and subjected to cold weather. The mitre type of heater, shown in "D," is especially adapted to hot-water heating, although it works well with steam. The general arrangements for air venting, drainage, and flexibility are indicated in the cut. This is the only pipe heater shown which meets the requirements of hot-water heating, and is recommended because the direction of flow is downward and the resistance is reduced to a minimum. While the size of standard bases will vary with different manu-

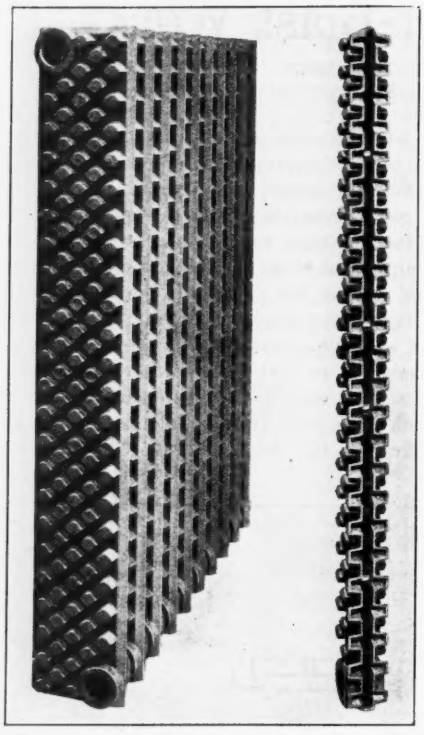


FIG. 2. CAST-IRON PIN TYPE HOT BLAST HEATER

facturers, they will commonly run from 3 to 9 ft. in length, varying by even feet.

Bases are commonly made for four rows of one-inch pipe, although some makers limit those for 1¼-in. pipe to two rows. The height of the heater can be varied within limits, to give the amount of heating surface desired.

In Fig. 2 is shown a cast-iron heater designed especially for hot-blast work. A group of assembled sections is shown at the left and a longitudinal section of a single unit at the right.

In the standard size, the depth of section corresponds closely with a four-row pipe heater and has about the same heating effect, both as regards efficiency and final temperature.

Assembly of Heater Sections

Assembly of the heater sections and the general arrangement with reference to the fan and cold air inlet will depend largely upon local conditions. For heaters of small and medium size, and also in factory heating, where high air temperatures and deep heaters are necessary, a steel casing around the coils is commonly employed. In factory work, the apparatus is usually supported upon a platform, without separating partitions, and the cold air brought to the heater through a duct, as indicated in Fig. 3A, while in other types of buildings a cold-air room, connecting with the outside by means of windows or an air-shaft, is made use of, as in Fig. 3B. For a high air temperature, the heater should be deep, which results in a smaller superficial area exposed to the entering air. For lower temperatures a shallower heater is required, with a larger superficial area. Two methods of increasing the area with shallow heaters, enclosed in steel casings, are shown in Figs. 3C and D. In the case of purely ventilating work, where the air is raised only to 70 deg., a comparatively large superficial area is required and the heaters are usually placed between brick walls, without the use of steel casings as in Fig. 3E. In the illustrations given, the "draw-through" arrangement has been shown; i. e., the air passes through the heater before it reaches the fan. This is commonly employed where the air is all to be delivered at one temperature, as in the heating of shops and factories, and

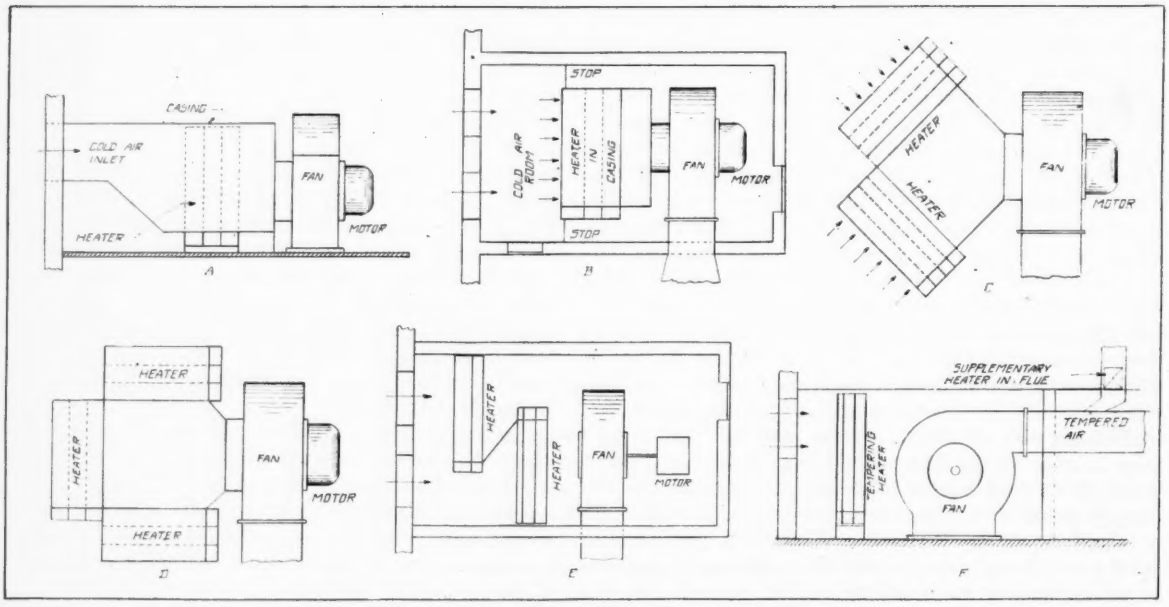


FIG. 3. TYPES OF FAN AND HEATER ARRANGEMENTS

A, draw-through fan with a simple casing over the heating coils; B, heater and fan in a separate room supplied from a coal air room; C and D, methods of providing additional superficial area at the heating coils; E, superficial area increased by use of brick wall baffles; F, blow through system with tempering coils and separate heating units in each delivery flue.

in the ventilation of large buildings of various kinds. It usually requires less space and produces a more uniform flow of air through all parts of the heater. This arrangement, however, increases the work of the fan somewhat, as the air being heated has a greater volume.

The "blow-through" arrangement is employed where air must be delivered at different temperatures to different rooms. A common plan in this case is first to draw the air through a tempering coil, raising its temperature to 60 or 65 deg., and then blow it through secondary heaters, before delivering to the various rooms. With this arrangement, each room has its individual

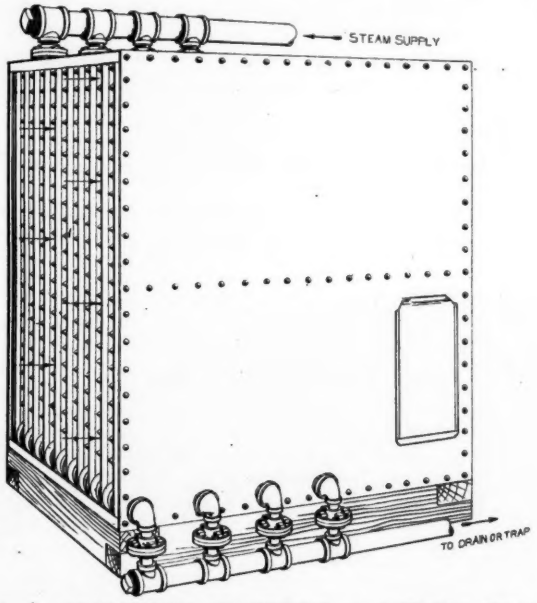


FIG. 4. ARRANGEMENT OF SECTIONS IN CAST-IRON HEATER

secondary heater, and the temperature may be regulated independently of the others.

Such a scheme is shown in diagram in Fig. 3F. When the cold air is first blown through a main heater for tempering, or for the entire heating, there is a tendency for a large part of the air to pass through the central portion of the heater at a high velocity directly in front of the fan outlet, unless they are separated by a considerable distance, or diffusers employed for spreading the air as it leaves the fan.

Ordinarily the general arrangement for cast-iron heaters is much the same as for those made up of pipe, the stack shown in Fig. 2 being heated as a four-row pipe section and encased in groups as in Fig. 4. The space occupied by a cast-iron heater for a given amount of heating surface will average about the same as for a pipe heater; some makers claim it to be slightly less, (about 15 per cent), while tests on certain forms have shown the advantage to be in favor of pipe construction in the ratio of about 12.2 to 8.4, much depending upon the makes of heaters compared.

Pipe heaters are commonly tested up to 180 lb. pressure at the shop and may be safely operated at 80 lb. Cast-iron heaters of the form shown in Fig. 2 are tested at 100 lb. and guaranteed up to a maximum working pressure of 40 lb. Cast-iron sections of the ordinary gravity indirect type should not, in general, be subjected to more than 20 lb. As a matter of fact, the steam pressure carried in hot-blast heaters does not usually exceed 5 lb., being about 1 lb. when exhaust steam is employed and 2 lb. for live steam. In some plants it may be desirable, for various reasons, to carry a higher pressure, and the safe working pressure for the particular type of heater used should always be considered in cases of this kind.

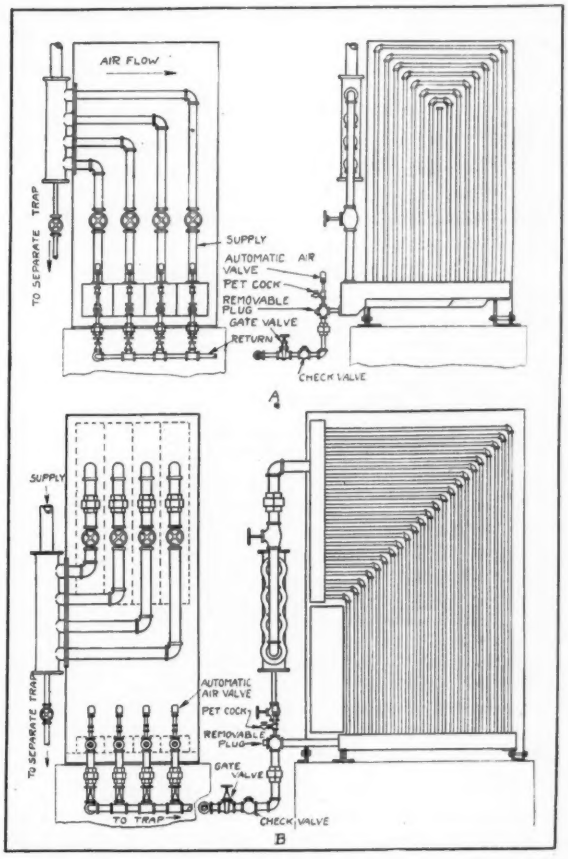


FIG. 5. CONNECTIONS FOR PIPE HEATERS: A, LOOP TYPE, AND B, MITRE TYPE

In hot-water systems the pressure must always be taken into account in making up the heater. For average work the static pressure will not usually exceed 30 or 40 lb. per sq. in., but sometimes the return valve is shut off while the pump is still running, in which case the full "no delivery" pressure will be thrown upon the heater and produce strains considerably in excess of those ordinarily carried under normal working conditions.

Pipe and Damper Arrangements

In making pipe connections the method used will depend somewhat upon the scheme employed for regulating the temperature of the air delivered to the building. In some cases, entire regulation is secured by valve manipulation, thus varying the number of sections in use. When this is done, it is a good plan to divide the heater into separately valved groups containing surface in the ratio of 1, 2 and 3; that is, in a heater 12 rows deep, there would be three separately valved sections, one having two rows of pipe, one four rows, and one six rows, in which case 2, 4, 6, 8, 10 or 12 rows of pipe

may be put into service by the possible combinations of the three pairs of valves. In general, the piping should be so arranged that the valves are easily reached for manipulation either from the floor or platform upon which the heater rests, or, in case of large units, from a special gallery or walk reached by a stationary iron ladder or stairs. Pockets in the piping should be avoided and the end of the main header drained through a separate trap. Typical connections for a four-section heater of standard form are shown in Fig. 5A. In this arrangement the valves are placed in the vertical drops

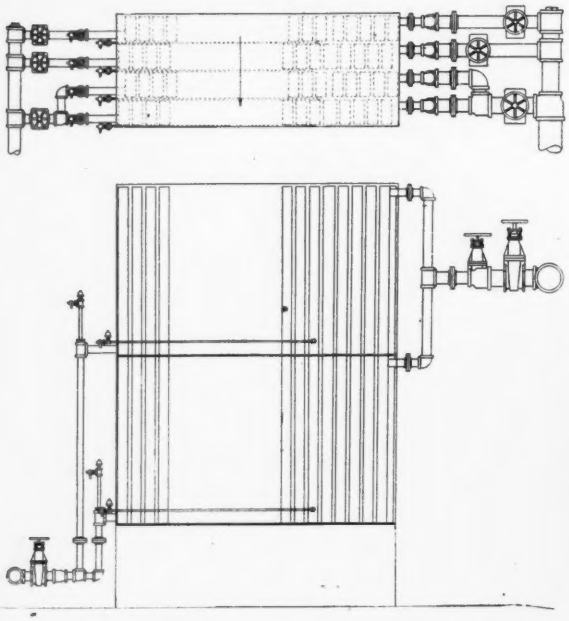


FIG. 6. SUPPLY AND RETURN HEADER CONNECTIONS FOR CAST-IRON HEATER ASSEMBLY

to make them accessible from the floor, which leaves a pocket above them for the accumulation of condensation. This will do no harm while portions of the heater are in use so there is no danger of freezing. If, for any reason, it were to be left idle in cold weather, the valve in the main supply should be closed and all valves in the branches opened so as to allow the heater and all supply and return branch connections to drain free of water.

In case of a small heater, the supply valves would be placed in the horizontal portion of the connections close to the vertical main header, as they would still be easily reached from the floor and all pockets would be eliminated.

Connections for a mitre heater are shown in Fig. 5B and require no special explanations.

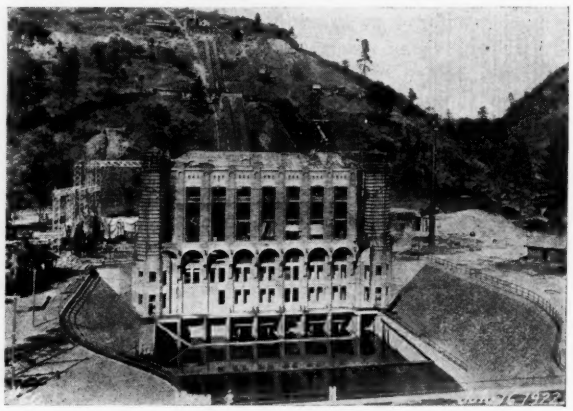
Special attention should be given to air venting by using large free opening automatic valves designed especially for this class of work. They are commonly placed in a cross or tee in the return connections at the point indicated in Fig. 5A. A hand pet-cock should also be provided for the quick removal of air when steam is first turned into the heater and also in case of emergency, should the automatics fail to work properly.

Typical connections for a cast-iron heater two sections high, are shown in Fig. 6. In heaters of this type, not exceeding 15 sections in width, the supply and return connections may be made at the same end of the stack. For greater widths, they should be at opposite ends as shown in the drawing. Heaters 12 sections and less in width will operate satisfactorily with a single air vent in the return from each group of sections. In case there are more than this number in each row, an additional vent should be taken from the middle section of each row as also indicated in the drawing.

Inspection of Hydraucone at Pit River Plant

TO PERMIT of the nspection of the hydraucones and stop logs of the Pit River Power Plant No. 1 after a portion of it had been in operation a short time, the water was pumped from the tail race and delivered to the down-stream side of the concrete weir shown in the foreground in the accompanying illustration. By thus pumping out the tail race, it was also possible to test the weir for leakage.

As a whole, the tail-race presents an unusually pleasing appearance. It is lined with concrete to a point a few feet above the water line and above this a rubble wall extends to the top of the canal where there is a fence of heavy piping imbedded in the concrete.



TAIL RACE AT PIT RIVER PLANT

Important Alaskan Coal Operation

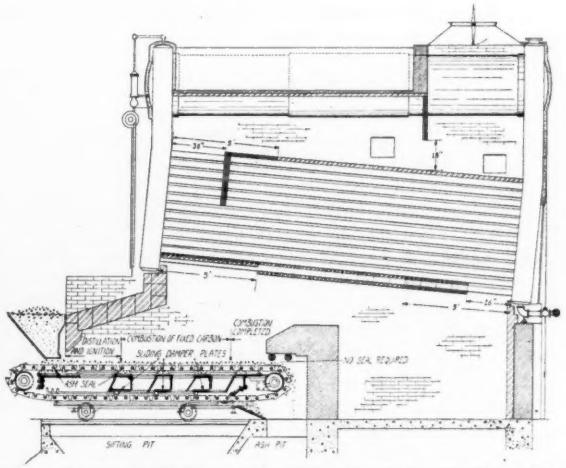
B. D. STEWART, supervising mining engineer for the Bureau of Mines in Alaska, has conferred with the officials of the Healy River Coal Corporation relative to the opening of this company's new coal mine on Healy Fork of the Nenana River. This mine is located in the Nenana field, 4½ mi. east of Healy on the Alaska railway, and is to be opened on quite an extensive scale. The coal is a good grade of sub-bituminous variety, and the beds are of unusual thickness. The new camp of the Healy River Coal Corporation has been christened "Suntrana," which, in the language of the Wood River Indians, signified "dust from sun" and is their word for coal. The opening of the Suntrana Mine is an important event, as it assures to Fairbanks, and all outlying camps reached by reasonably good transportation facilities, a plentiful supply of coal of satisfactory grade at low cost.

Economical Steaming Secured at Partial Loads

ZONE COMBUSTION CONTROL FOR CHAIN GRATE AND REVISION OF BAFFLE ARRANGEMENT EFFECT FUEL ECONOMY IN OFFICE BUILDING

TO WORK a boiler at say one-fourth its normal rating and get anywhere near full load efficiency has always been a problem of considerable moment to the engineer of a plant where the load falls off to a fraction of the boiler rating during a comparatively long period of operation as is likely to occur in office buildings and industrial power plants. It has long been recognized that every furnace has a certain rate of fuel combustion at which its efficiency is highest, to increase or decrease this rate means to lower the efficiency.

Such was the condition that existed in the plant of the North American Building in Chicago. During the daytime the load on the boilers remained fairly constant



STEEL PLATES PROPERLY ARRANGED IN CHAIN GRATES MAKE ZONE COMBUSTION CONTROL POSSIBLE

around normal rating with peak load periods about noon and in the early evening. At night, however, the load dropped to a low percentage of the rating of the boiler that was kept in service with a marked decrease in boiler efficiency.

To hold the rate of combustion down to the requirements of the load conditions resulted in an excess of air through the ash bed at the rear of the chain grate stoker and a comparatively cold furnace, making ignition difficult and combustion of the gases incomplete. A study of the stoker design indicated that by means of steel plates the grate could be divided into zones to which the air could be controlled or shut off entirely, thus shortening the length of the combustion zone, virtually reducing the grate area and making it possible to maintain the desired rate of combustion per square foot of grate area for any probable load on the boiler.

It will be noted in the illustration that four of these steel plate boxes are provided which extend the width of the grate. On the flat surface at the top, ashes collect and act as air seals. Three sliding damper plates, operated by levers at the front of the stoker, control the passage of the air between the boxes to the different sections of the grate.

Considerable improvement in economy was also obtained by a rearrangement of baffles from that originally employed. The 250-hp. Edge Moor water tube boilers, with which the plant is provided, are horizontally baffled. The lower baffle is made up of T tile for 5 ft. from the front of the boiler, the remainder to within 26 in. of the rear water leg is C tile. At the front end of the upper baffle a short vertical baffle is dropped six tubes, deflecting the gases downward and around the front ends of all the tubes. A baffle was also placed below the drum at the point just ahead of the gas passage to the breeching. The changes which were made are shown cross hatched in the illustration and consisted in reducing the gas passages at the end of the lower baffle from 60 to 26 in. and that at the end of the upper baffle from 60 to 30 in., and the addition of the two vertical baffles.

These changes had the effect of bottling up the heat around the tubes and drum and gave a reduction of 125 deg. in flue gas temperature.

At all times the flue gas analysis shows 12 per cent CO_2, regardless of the load carried on the boilers, and an actual evaporation of 8 lb. of water is secured with No. 4 Southern Illinois coal. The feed water temperature is 200 deg. or more and the steam pressure carried is 150 lb. When working the boilers at 140 per cent rating the stack temperature is about 650 deg.

Although with chain grate stokers having zone combustion control forced draft is usually employed, no difficulty is experienced here in securing sufficient draft to operate the boilers at 230 per cent rating. Under ordinary normal load conditions the draft over the fire is around 0.04 in. water and at the damper 0.2 in.

Marked savings have resulted from the changes noted above which have come gradually through a number of years as a matter of development in boiler practice.

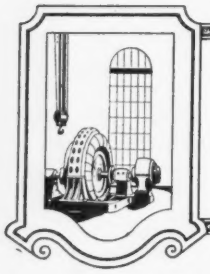
Spontaneous Combustion of Coal on Shipboard

SERIOUSNESS of fires on ships due to spontaneous combustion in bunker and cargo coal has led the Department of the Interior to undertake a study of causes and means of prevention, results of which are given in Technical Paper 326, by H. H. Stoek, just issued by the Bureau of Mines. While the paper refers directly to spontaneous combustion on shipboard, the information may also be of value to those responsible for the storage of coal on land.

Liability to spontaneous combustion is greatly reduced if fine coal and dust be removed by screening, but this is usually not practicable with present coaling methods and because run-of-mine coal is generally furnished to ships, particularly at American ports, both for cargo and bunker purposes. This requires that extra precautions be taken. The least friable of the coals available should be chosen, if possible, and care used in handling the coal to minimize breakage and crushing.

It is wise to select a low-sulphur coal, if possible; but it must not be taken for granted that a low-sulphur coal will be free from spontaneous combustion.

Practice and opinions vary widely in regard to the ventilation of bunkers and holds. Many advocate keeping the coal spaces as nearly air tight as possible by battening down the hatches, but others advocate taking off the hatch covers, when weather conditions permit.



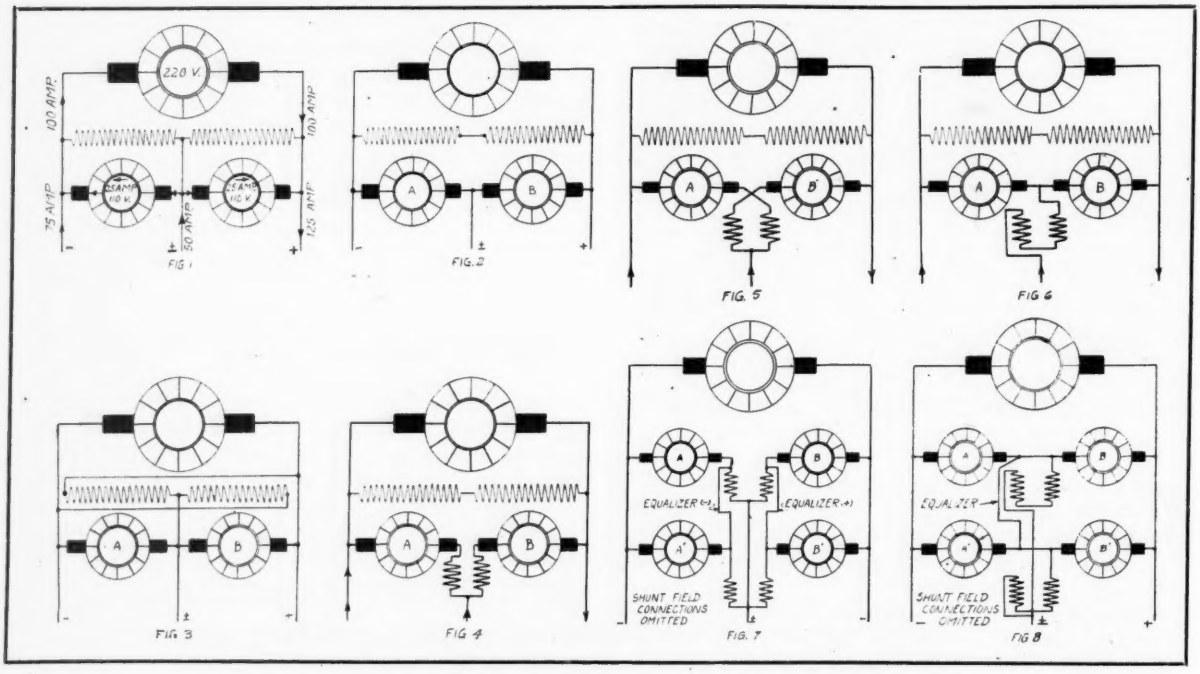
ELECTRICAL MACHINERY FOR LIGHT AND POWER

Operating Features of Generating Equipment--III

General Considerations Regarding Three-Wire Generating Equipment and Methods of Connecting. By V. E. Johnson

THREE-WIRE direct current distribution requires the use of one of the following three methods of generation:

1. An ordinary two-wire machine and a balancer set.
2. Two direct current machines in series.
3. A three-wire generator.



FIGS. 1 TO 5. BALANCER SETS PERMIT OF A VARIETY OF CONNECTIONS

Fig. 1. Simple method of connecting shunt wound balancer set. Fig. 2. Balancer set with shunt fields connected in series across outside mains. Fig. 3. Balancer set with shunt field connections reversed. Fig. 4. Balancer set using compound wound machines. Fig. 5. Connection in which the series fields are crossed. Fig. 6. In this connection the series fields carry the neutral current. Fig. 7. Balancer set having the series fields separate. Fig. 8. A connection to Fig. 7 but with series fields in the neutral circuit.

Fundamentally, the first method is very simple; but there are a number of interesting field connections each of which produces somewhat different results.

One of the simplest methods of connection is shown in Fig. 1 in which the two machines are identical and are rigidly connected to each other. Electrically, they are connected in series and float on the line. If, due to a difference in load on the two sides of the machine, the voltage of the system becomes unbalanced, the machine on the "low" side acts as a generator thereby raising the voltage, while, simultaneously, the other machine acts as a motor, driving its mate and, by imposing a load on the "high" side tends to reduce the voltage on that side.

In Fig. 1, for example, the positive side of the system is carrying 50 amp. more current than the negative side. These 50 amp. flow back through the neutral and, in effect, the machine A runs as a motor and B as a generator. This boosts the voltage from positive to neutral and reduces the voltage from negative to neutral, thus establishing a balance.

It will be evident also that under the unbalanced conditions the field on machine A is stronger than the field of B because the voltage across A is higher. As a consequence, the re-established balance is not perfect; A, having a stronger field, will run slower as a motor, while

B, having a weaker field, will generate less voltage—both conditions operating against a return to balance.

In Fig. 2 is shown a connection which is practically the same as that shown in Fig. 1 except that the shunt fields are in series across the outside mains and have no connection with the neutral. The fields are therefore of equal strength at all times and the disadvantage referred to in connection with Fig. 1 is eliminated.

Figure 3 gives still better regulation for here the field of the machine on the low voltage side, as for instance at B, is across the high voltage side—and vice versa. In other words, the motor field is weakened—tending to increase the speed—while simultaneously the field of the generator is strengthened further raising its voltage.

In Fig. 4 is shown a balancer set using compound wound machines. Under unbalanced conditions the field on the motor becomes "differential"—that is, the series fields oppose the shunt fields—and so tend to increase the speed. The generator series fields assist the shunt fields and so increase the voltage. This method can be used with the shunt field connection of Figs. 1, 2 or 3. The sketch shows the method of Fig. 3. This straight series connection, has, however, the disadvantage that on severe unbalance it may so weaken the field as to cause a runaway—or if prevented from this by the braking effect of the generator, a flashover.

Figure 5 shows a connection with series field crossed. This overcomes the unstable characteristics of the straight series connection, but also is not quite as accurate, as under unbalanced conditions it slows the motor down, and weakens the generator field.

An entirely different form of connection is shown in Fig. 6 for here the series fields carry the neutral current instead of the machine current. For instance, with the unbalance indicated in Fig. 1, the fields would carry 50 amp. instead of 25. The designer would naturally take this into consideration, but it is possible to get a little closer regulation with the higher current.

Any of the foregoing series connections can be used in conjunction with any shunt connection. With the shunt field arranged as in Fig. 1, a field rheostat can be put in series with each half, so that the regulator can be controlled by hand.

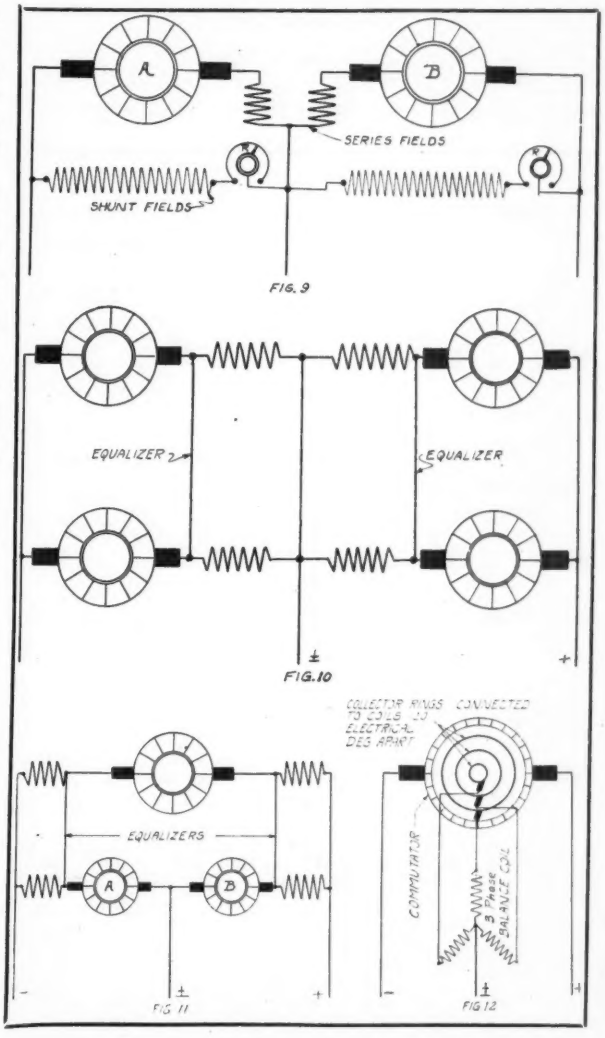
If balancer sets are to operate in parallel, the general principle involved is that of generators under similar conditions. That is, shunt wound balancers are merely connected across the mains—and when at full speed connected to the neutral, while compound wound sets must have equalizer connections—either one or two—depending on whether or not the series fields are in one or two circuits.

In Fig. 7 is shown the connection for the balancer sets having their series fields separate. As far as the equalizer goes it would not matter whether the series fields were crossed or straight, but obviously all sets in parallel would have to have similar connections.

Figure 8 shows the connection when the two series fields are in the neutral circuit. Here it is necessary to use one equalizer only as both series fields necessarily carry the same current.

Two D. C. Machines in Series

This is the second method of obtaining three-wire service as given in the classification at the beginning of this article. Figure 9 shows the connections in a simple form, but for compound units operating in parallel with other three-wire generators, the connection is complicated by the addition of an equalizer. The need for this is self evident, as each half of the combination is really in parallel with the corresponding half of the set with which it is to operate. In Fig. 10 are shown the



FIGS. 9 TO 12. THREE-WIRE CIRCUITS MAY BE FED BY GENERATORS CONNECTED IN SEVERAL WAYS

Fig. 9. Three wire system using two d.c. generators in series. Fig. 10. Two compound machines arranged for three-wire operation with equalizer connection. Fig. 11. Showing method of splitting series winding. Fig. 12. Simple diagram of three-wire generator.

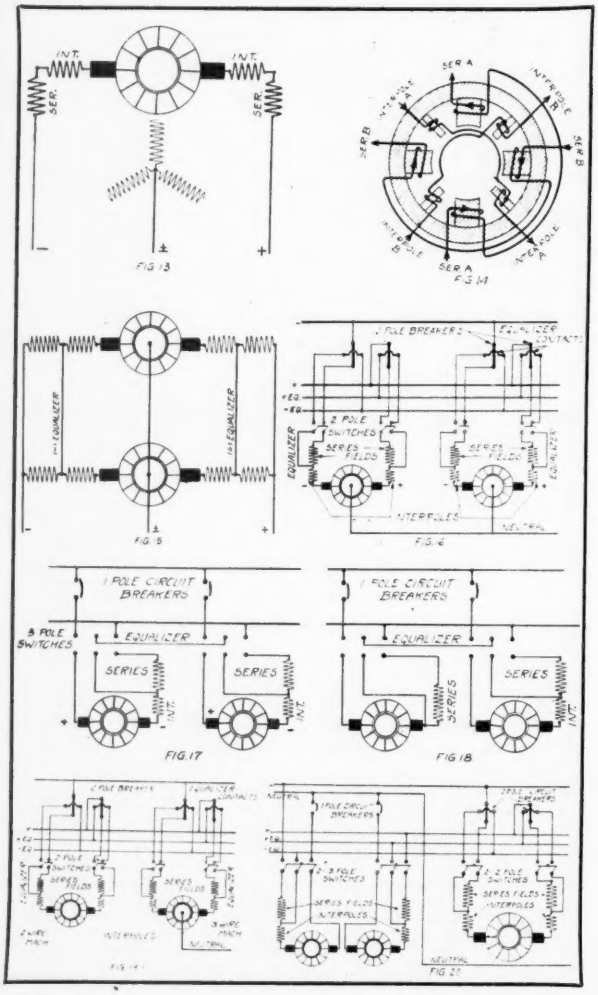
equalizer connections. These, as will be noted, are essentially the same as for the balancer set in Fig. 7. In this case, however, the machines are driven by an external prime mover so that there is no great danger of unstable operation where the series fields are connected straight.

If a set of generators so connected are to operate in parallel with a two-wire machine, it is necessary to split the series field winding of the latter into two halves. This is done by putting all the north poles in one circuit,

and all of the south poles in the other. A double equalizer is used. Fig. 11 shows this arrangement. This, however, must not be confused with the balance set connection of Fig. 7, as in that case the units A and B ran as motors, while in this case A and B are driven independently of the main generator and *both* are normally generating instead of one motoring.

The Three-Wire Generator

Of late years, the methods just described have become practically obsolete and the third method—that employing a three-wire generator—is used. Figure 12 shows the external connections of a machine of this type. The balance coil in this case is merely a three-phase iron core, choke coil, three coils being connected as shown, this being commonly called a Y or star connection. While Fig. 12 shows a three-phase balance coil, this is not the only combination that will operate. The object of using the balance coils is to obtain a "halfway point" between the positive and negative brushes. An auxiliary brush located halfway between the main brushes would, in a sense, divide the voltage; but commutator difficulties make this method impractical. The balance coil through the slip rings is connected to the armature coils themselves and so has alternating current circulating through it. The flow of current is limited by the self induction of the coils and at balanced loads is very small. Under unbalanced conditions, the neutral current is drawn through the coils from the rings.



FIGS. 13 TO 20. USE OF INTERPOLE OFFERS VARIETY OF CONNECTION ARRANGEMENTS

Fig. 13. Schematic arrangement of three-wire interpole, compound wound machine. Fig. 14. Showing method of connecting field poles and interpoles. Fig. 15. Two interpole machines in parallel showing equalizer connection. Fig. 16. Wiring diagram of two interpole machines in parallel. Fig. 17. Actual switching connections of two compound interpole machines in parallel. Fig. 18. Interpole and non-interpole machines in parallel. Fig. 19. Three-wire machine in parallel with two-wire machine. Fig. 20. Three-wire interpole machine with two 2-wire interpole machines.

Paralleling Three-Wire Machines

Paralleling shunt wound three-wire generators is very simple, but when compound wound generators are used, the connections become quite complicated. If the machine also has interpoles, the scheme of connections is still more confusing.

In order that proper compounding and proper compensation may be obtained under all conditions of unbalance, it is evident that both the series field windings and the interpole windings must be in halves and so connected that the positive current passes through one half of each, while the negative current passes through the other half. Figure 13 shows the schematic arrangement of one three-wire, interpole, compound wound machine. In order to obtain symmetrical field distribution it is customary to place the positive half of the series and interpole windings on alternate field poles, and the negative halves on the remainder. This is shown roughly in Fig. 14, which is made four-pole for the sake of clearness. The same scheme would apply to any number of poles.

For parallel operation then, equalizers would be necessary on each side of the series field, as shown in Fig. 15. After the connections have been properly made, the operation is not much different from that for two-wire machines. It is customary to place the equalizer contacts on the circuit breakers, and to arrange the main switches as shown in Fig. 16. Voltage is read only across the terminals of the machines—disregarding the neutral—so that the operation of placing the generators in parallel is the same as if they were two-wire.

Paralleling Mixed Types

So far, consideration has been given to the paralleling of similar types of machines only; however, it is frequently necessary to parallel dissimilar types and to cover these cases, the diagrams in Figs. 17 to 20 are given. The connections are arranged approximately as they would be in actual practice except that the meters are omitted.

Figure 17 shows two compound wound-interpole machines in parallel. This has been discussed—but this diagram shows the actual switching connections. Figure 18 shows two compound machines in parallel—one having interpoles—the other not. Figure 19 shows a three-wire compound wound interpole machine in parallel with a two-wire compound wound interpole machine. Figure 20 shows a three-wire compound interpole machine in parallel with two machines in series, each of these machines having a compound and interpole winding.

Current Capacity of Wires and Cables

With Short Circuits, Temperature Is Usually the Limiting Factor Determining Size of Wire. By George E. Luke

IN THE TRANSMISSION of electric power the size of the wire or cable to be used may be determined by any one or more of the following factors: the line voltage drop, the power loss, the temperature of the cable or its mechanical strength. For long transmission lines the dominating factor is power loss, while with short lines the important factor may be the maximum safe temperature of the cable. The temperature of the wire or cable has a considerable influence on its ultimate tensile strength. For example, ordinary drawn copper will start to anneal at temperatures above 100 deg. C. Tests have shown a reduction of strength of 12 per cent due to temperatures of 130 deg. for 72 hr.; a reduction of 30 per cent at a temperature of 150 deg. for the same

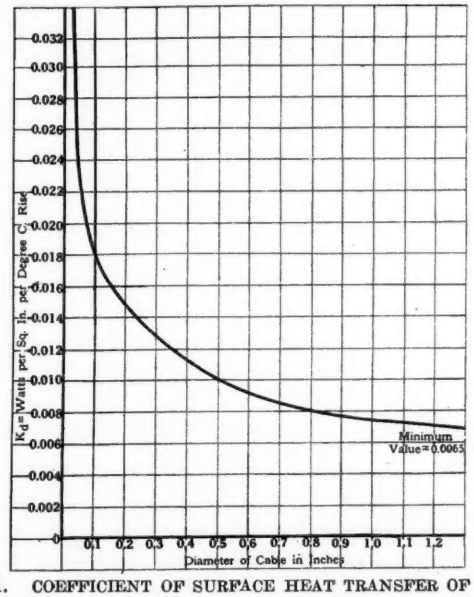


FIG. 1. COEFFICIENT OF SURFACE HEAT TRANSFER OF BARE AND INSULATED WIRE AND CABLE (WITH NATURAL VENTILATION IN STILL AIR)

time; and complete annealing at 200 deg., with a reduction of 45 per cent. A few tests on aluminum wire indicated approximately the same results.

Hence, where mechanical strength is a factor, for example in long transmission spans, the bare wire should never be loaded so as to give temperatures above 100 deg. C. This should also be the limit for bare wires, strap or cable that come in contact with a fibrous insulating material. Another temperature limit which may be found in some special applications is the melting point of common solder, or approximately 180 deg. C.

Insulated wire or cable has a lower limit than the values above given. The American Institute of Electrical Engineers Standards of 1922 gives these limits:

Maximum Safe Temp. Deg. C.	Kind of Insulation
85-E	Impregnated paper
75-E	Varnished cambric
60-E/4	Rubber

Where E is the operating voltage in kilovolts between conductors.

Since all inside and exposed wiring must be done with insulated wires, and since the length of such wiring is comparatively short, the temperature of the wire will

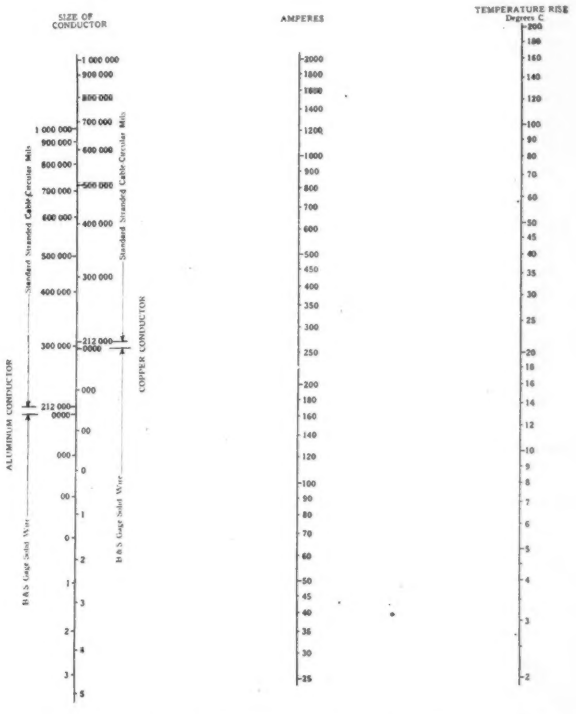


FIG. 2. CHART FOR DETERMINING THE CONTINUOUS CURRENT CAPACITY OF BARE COPPER AND ALUMINUM WIRE AND CABLE IN STILL AIR

usually be the limiting factor in determining the size of the conductors to be used.

For Continuous Rating Heat Must Be Liberated as Generated

Bare wire and cables.—The heat loss in a cable resulting from the I^2R losses on continuous duty must be liberated as fast as it is generated. This dissipation of heat can only be done by an elevation in temperature of the cable above the surrounding medium. The following data are the results of a series of tests regarding some of the principal factors affecting the heating of cables and wires. The following approximate conclusions were drawn from the foregoing with regard to the liberation of heat from the surfaces of the wires and cables.

1. The temperature rise of the surface of the wire or cable above the surrounding air is practically proportional to the watts loss on continuous duty. In other words the transfer of heat from the surface in terms of watts per square inch of surface per degree Centigrade rise of the surface can be taken as a constant.

2. The preceding coefficient of heat transfer by natural ventilation increases very rapidly for small diameter wires and cables as the diameter decreases.

3. For the same size cable or wire, this unit heat dissipation constant did not differ greatly for a smooth copper, lead or aluminum; a stranded copper; or an armored or an insulated surface, either black or white in color.

4. The surface heat loss coefficient for a wire suspended in a large room with only natural convection air currents was practically the same as that found for the wire suspended out of doors during a dead calm day. Also the coefficient was practically independent of the wire position.

Values of this surface dissipation constant K_d are shown in Fig. 1 for wires or cables of various diameters.

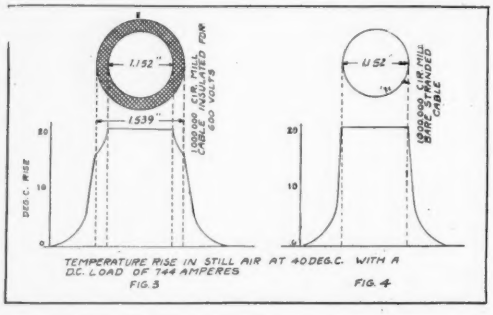


FIG. 3. TEMPERATURE GRADIENT OF A COPPER CABLE COVERED WITH A SLOW BURNING INSULATION

FIG. 4. TEMPERATURE GRADIENT OF A BARE STRANDED CABLE

The curve represents the average of many tests, taken on all sizes of bare and insulated wires. The curve shows a very rapid increase in this constant for a decrease in the size of wire. With this constant known, the current capacity of a bare cable can be determined for any temperature.

Since the loss

$$I^2R = 3.1416\ d\ L\ K_d\ T$$

$$\text{Then} \quad I = \sqrt{\frac{3.1416\ d\ L\ K_d\ T}{R}}$$

Where I = continuous current capacity in still air, in amp.
d = diameter of bare cable in inches
L = length of cable in inches
K_d = dissipation constant obtained from Fig. 1.
T = deg. C. continuous temperature rise of the cable
R = resistance of the cable (length L) at its continuous temperature (T plus air temperature)

Thus the capacity of a 1,000,000 circ. mil. bare stranded copper cable with a temperature rise of 40 deg. C. in 40 deg. C. room air will be

$$I = \sqrt{\frac{3.1416 \times 1.152 \times 12{,}000 \times 0.0072 \times 40}{0.01305}} =$$

980 amp.

For aluminum cable of the same size, the same watts loss can be liberated; however, since its resistance is different, the current capacity will not be the same as for copper. For convenience in determining the current capacity of bare copper and aluminum wires and cables, the foregoing formula has been plotted in nomographic form in Fig. 2.

Insulated Wire

In an insulated cable the flow of heat due to the I^2R losses must be accompanied by a temperature drop through the insulation as well as a surface temperature gradient. It can be shown that:

$$I^2R = \frac{L \times T}{\frac{2.3}{2 \times 3.1416\ K_t} \text{Log}_{10} \frac{D}{d} + \frac{1}{3.1416\ D\ K_d}}$$

Where—I, R, L, T, d and K_d are as previously defined.
D = outside diameter of insulated cable in inches
K_t = coefficient of thermal conductivity of the insulation in watts per cu. in. per deg. C.
= 0.0050 for rubber insulation
= 0.0030 for varnished cambric and impregnated paper
= 0.010 for slow burning insulation.

These figures are averages since the coefficient varies considerably.

In Fig. 3 is given the temperature gradient of a 1,000,000 circular mil insulated copper cable. This

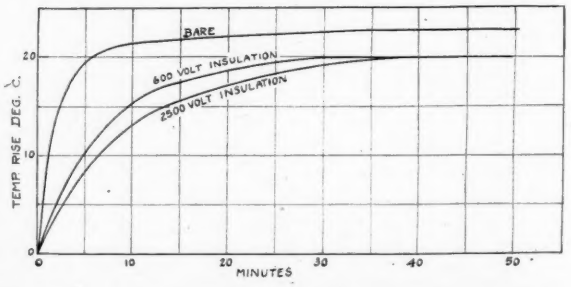


FIG. 5. HEATING CURVES OF BARE AND INSULATED 31,600 CIR. MILS CABLES

shows that with a 20 deg. C. copper temperature rise (744 amp.), 17.4 deg. are required to dissipate the heat from the outside surface, and the remainder or only 2.6 deg. are required to conduct the heat losses through the insulation. Figure 4 shows that the same cable, bare, with the same current will have a temperature rise of 21.6 deg. The fact that an insulated cable may have a

FIG. 6. METHODS OF GROUPING CABLES

lower temperature rise than the same cable bare for a given load may seem paradoxical at first. In the case cited, however, the decrease in the surface temperature drop by the increased diameter, due to the addition of the insulation, more than neutralized the small increase in temperature drop necessary to conduct the heat through the insulation.

Figure 5 shows the heating of a 31,600 circ. mil copper cable with 84 amp. load, bare and also with 600 and 2500-v.-insulation. The bare cable gets hottest, while the continuous temperature of the 600-v.-insulated cable was the same as the 2500-v.-insulated cable. The effect of insulation on a cable is not always the same as given.

For example, insulation on some sizes of bare cable will increase its temperature. In general, the effect of the insulation will depend upon the size of cable, insulation thickness, type of insulation, and ventilation. An increase in ventilation (or an increase in K_d) will reduce the surface temperature drop and increase the relative importance of the temperature drop through the insulation.

Grouping of Cables

Cables grouped together such as shown in Fig. 6 will be hotter than when separated. An approximate method of calculating the current capacity under these conditions is to replace the expression $\frac{1}{3.1416\,D\,K_d}$ (in the equation previously given) by $\frac{N}{P\,K_d}$ where N is the number of cables and P the periphery of the bundle in inches. A cable should not be totally surrounded by others, since the temperature of the enclosed cable will be considerably higher than those of the outside cables. —Electric Journal.

Concrete Poles Made by Centrifugal Process

Concrete Poles for Large Swedish Power Line Will Bend 7½ Ft. Without Breaking. By F. A. Brackmann

BECAUSE OF the high price and the cost of maintenance of iron structures, and of the comparatively short life of wooden poles subjected to the weather, reinforced concrete poles are receiving considerable attention these days, particularly in Europe.

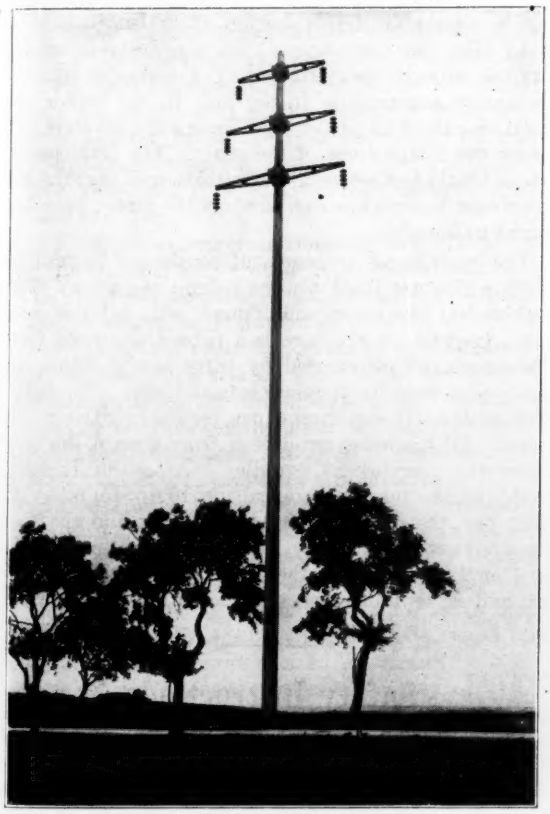


FIG. 1. CONCRETE POLE OF A POWER TRANSMISSION LINE, 103 FT. HIGH

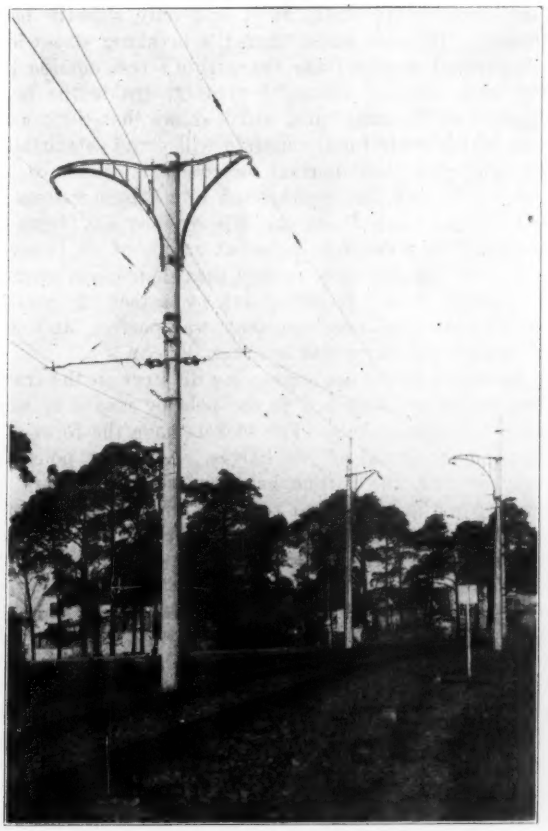


FIG. 2. SHOWING REINFORCED POLES CARRYING THE OVERHEAD WIRE OF AN ELECTRIC RAILWAY

Such poles are generally produced by the centrifugal process, and various designs and shapes are being brought on the market. One of the largest power transmission lines of this kind is that which forms a connection between the networks of South and Central Sweden from the works at the Trollhaettan Falls to Vaestreros in Sweden, northeast of Stockholm. It was built for transferring the surplus energy from the Trollhaettan Falls to the station at Aelfkarleby, especially during the winter, when the water of the Dalaelfs is insufficient to produce the energy required. The line, which is about 200 mi. long, is carried by structures of hollow reinforced concrete poles and transmits at present current of 110,000 v. It is intended to increase the voltage to 240,000 later on. Altogether 800 poles were used, which were erected in pairs. The first few hundred were connected by an iron transverse beam, but in view of the favorable experiences made in the course of construction with the concrete poles, reinforced hollow beams were used later on.

These carry two cables between the poles and two at the ends outside. The length of the cross beam amounts to about 54 ft., and the width between the two poles about 36 ft. According to the changing local conditions along the line, and the variations in the load from 1200 to 1400 lb., four different sizes were made from 56 to 59 ft. in height, and a diameter from 9 to 10 in. at the top and from 18.5 to 23 in. at the bottom. The average wall thickness is 2 in. Nearly 6 per cent of them were tested, and some of them, about 1 per cent of the whole number, were subjected to bending stresses till fracture occurred.

It was stipulated that the latter had to withstand at least four times the highest ultimate load at the top. The others had to be subjected to double that load without showing any cracks or alterations of form. The tests proved, however, that the poles were exceedingly elastic, and could carry six to eight times the highest ultimate top load. During the tests the load was taken off several times, and the top went almost completely back into its original position, showing that the bending was of an entirely elastic nature. Even after fracture had occurred, the steel reinforcement was still able to stand considerable stress as it had only slightly been damaged. In some cases when the breaking stress had been reached, cracks from the tensile stress outside the bend, and signs of excessive pressure inside the bend appeared at the same time, which shows that the tensile stress which centrifugal concrete will stand is considerably above the usual normal for concrete. Some of the poles, 64 ft. long, being subjected to a bending stress of 7300 lb., bent 7½ ft. at the top without any signs of damage. The poles were tested at an age of six to seven weeks. It had also to be proved that their earth connection, which was brought about by attaching contact pieces to the steel reinforcement, was perfect, and that the electric resistance was less than 0.2 ohm.

As shown in the accompanying illustration the transverse beams are attached to the pole by means of reinforced concrete sockets. The sockets have the form of a bearing and consist of two halves. After the poles are singly erected, the bottom halves of the sockets are set right upon the poles, and filled in with cement. Then the transverse beam is laid in, and the top halves of the sockets are screwed down. The recesses for the nuts and the ends of the bolts are also filled in with cement to prevent rusting, and the whole structure forms a complete unit at the finish. For the pulling up, and for the fitting of the sockets and cross beam, small iron appliances with a platform and with overhead pulleys are screwed to the poles. The pulley is used for the hauling up of the cross beam, the socket, and the material. After the finish of one structure these appliances are taken down and used on the next.

Of the poles and the beams which were manufactured at the works of a German firm at Cossebaude, near Dresden, two-thirds were transported by rail the whole way, via the ferry Sassnitz-Trelleborg, and the rest were shipped by lighters from Stettin. Considering the great stresses to which the transport subjected them, it speaks well for their quality, that all arrived in first class condition.

Poles Made in Wooden Mould

These poles are manufactured in a wooden mould, which is revolved in a special machine. The mould consists of two half round forms, and is lined with iron sheet inside. The reinforcement is formed by rolled rods, or open hearth material, going lengthwise, which are interwoven with three spirals of wire one within the other. It is wound upon a special automatic machine, so that the uniformity in their measurements and in the strength of the poles is ensured. The spirals influence the fracture stress comparatively little, but they determine to a certain extent the rigidity of the pole, and by using three spirals it has been possible to reduce the bending to one-half per cent of the length at the normal load, and to one-and-one-half per cent at the double load. In order to give the maximum strength to the pole, care is taken that the reinforcement comes as close as possible to the circumference, and is at an equal distance away from it. The cement mortar is mixed in proportion of one to three, and some asbestos fiber is added to assist in holding sand and cement together.

After the wire structure and the cement have been put into the mould, this is closed, and put into the machine. According to the diameter of the pole, it is then revolved at a speed of 500 to 1000 r.p.m. This high velocity, which it attained immediately after starting, and continued revolution at the same speed, are necessary to prevent a decomposition of the mortar, which would take place on account of the different specific gravities of sand and cement. The excessive water in the mortar accumulates in the hole in the center, and in striking the wall of the pole during the revolving, increases the compactness of the grain. The fear that the cement would be thrown to the outside, and that the mixture would become less rich towards the center have been proved unfounded.

The centrifugal arrangement consists of several machines which are lined up one behind the other. Each machine has two strong side frames with a large center bore. Inserted in the bore is a tube which rolls freely between six wheels carried by three shafts which may be adjusted radially in relation to the bore. The tube is fitted with a self-centering chuck for holding the wooden mould. All machines are driven from a main shaft, the center tube serving as a pulley. After revolving the mould in the machines for about 10 to 15 min. it is taken out, the lid at the end is removed, and the water is poured out of the center. The pole is left in the mould for 1 or 2 days. It has then set sufficiently to be taken out, and is kept in moist sand for about 3 to 4 weeks.

Safety Instructions

These should be given out to each employe, whether or not he or she professes to be experienced before starting work. Difference in materials, methods, machines and appliances may militate against the safety of even experienced operatives. One has only to note the number of accidents to hunters of long experience, to see how slight differences in conditions bring in an element of unexpected danger.

Where there is any likelihood of some of the workers being unfamiliar with English, the instructions should be polyglot, or be interpreted orally. In any case, they should be read aloud by either the foreman or the operative.

Robert Grimshaw.

The Rheostatic Type of Voltage Regulator

By J. H. Ashbaugh*

THE RHEOSTATIC type of alternating current generator voltage regulator differs fundamentally from the vibrating type in that the new regulator maintains a constant alternating current voltage by means of the generator field rheostat, keeping the excitation voltage at a constant value, whereas in the vibrating regulator, the exciter voltage is varied in order to give the proper excitation current to the generator for a given load condition.

This type of regulator supplements the vibrating type of regulator for such applications as are not best adapted to the use of the vibrating regulator. It is not the intention that the rheostatic type of regulator should supersede the vibrating type, but each form of regulator has its own particular field of application. The rheostatic type of regulator is particularly applicable to installations where the time constant (or rate of response to change in voltage on the field of a generator) is slow, where exciters are of large capacity and slow speed, thus having heavy field currents beyond the capacity of the vibrating regulator contacts, or for synchronous condenser application, where the excitation voltage across the field of the condenser must be lowered to a value below the residual voltage of the exciter, as is very often the case.

The rheostatic type of generator voltage regulator consists of 3 portions:

(1) A control element mounted in a suitable glass case, and located either on a panel which will be part of the main switchboard, or on a bracket or a pedestal as station design may warrant.

(2) A pair of reversing contactor switches actuated from the main contacts of the control element. The reversing switches are for operating the rheostat motors in one direction or the other, and may be mounted on the same panel with the control element or on a separate base in the rear of the switchboard.

(3) A special generator field rheostat operating at a high rate of speed, but so constructed as to produce a minimum amount of wear even if continually in motion. The motor of the rheostat is quickly brought to rest by so connecting the reversing switches as to employ dynamic braking the moment the control element ceases to cause a change in the excitation current.

The control element consists essentially of a set of contacts jointly actuated by an alternating current and a direct current coil. These contacts control the direction of rotation of the rheostat motor through two reversing contactor switches. The alternating current coil is connected to the generator lead through the use of a suitable potential transformer. The direct current coil is connected across the terminals of the generator field. A current coil is also provided together with a suitable number of taps for compensation purposes.

Anti-hunting features are incorporated in the design, and consist of auxiljary contacts on the reversing switches which automatically change the strength of the current in the alternating current coil at the moment there is a change in excitation voltage on the machine.

*Engineer with Westinghouse Electric & Mfg. Co.

The operation of the rheostatic regulator is exactly the same as if the station operator were regulating the voltage by hand. When the line voltage is at the correct value, the regulator is in equilibrium, and consequently there are no moving parts. Should the voltage deviate from the correct value, the regulator will operate the generator rheostat to bring the voltage back to normal.

Figure 1 shows a simplified wiring diagram of this regulator and will be referred to in the following discussion of just how the regulator operates.

Assume that a slight over-voltage exists on the generator, due to a sudden drop of a portion of the load. This will cause the control levers to become out of balance, and close the upper contacts. This closure energizes the upper coil and de-energizes the lower coil of the reversing switch marked "LS" causing con-

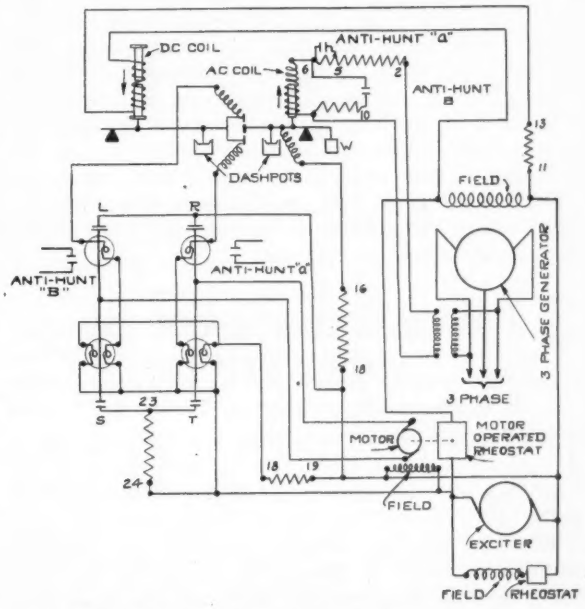


FIG. 1. SCHEMATIC DIAGRAM OF RHEOSTATIC REGULATOR

tact "S" to open, and contacts "L" and "B" to close Contact "L" closes the circuit through the motor armature which in turn, starts cutting in resistance of the generator rheostat into the field circuit. At the same moment, contact "B" shunts a small amount of current from the alternating current coil on the control element, and in effect, recalibrates it for a slightly higher voltage. This causes the core to drop opening the main contact which in turn de-energizes the coil in the upper and lower portion of the reversing switch "LS" and this switch consequently opens its main contact "L" and auxiliary contact "B" and closes the lower main contact "S." Since contact "T" of the other reversing switch is in the closed position, the armature of the motor is now short circuited, causing it to stop quickly by the dynamic braking. This causes an intermittent movement of the rheostat arm generally known as "inching," and effectively prevents hunting when the alternating current voltage is very nearly correct. In a like manner, if the alternating current voltage is too low, the main control element closes its lower contacts due to the core dropping in the alternating current coil and actu-

ates the reversing switch "RT" closing contacts "R" and "a" which in turn, reverse the direction of rotation of the rheostat arm, increasing the excitation and bringing the voltage back to normal. Due to the anti-hunting contact "a" which in this case cuts out a portion of the series resistor of the main alternating current coil of the control element, the "inching" process is also obtained.

The function of the direct current coil of the control element is to prevent hunting on extreme changes in alternating current voltage. Assume the alternating current generator to be suddenly subjected to an extreme overload, thus dropping its terminal voltage 15 or 20 in. The main contacts will immediately close in the proper direction, and remain closed until the voltage returns to very nearly normal value. Due to the high speed of the motor operated rheostat, and the inductance of the generator, the voltage across the field is increased at a faster rate than the field current. As the voltage rises across the field of the generator, the strength of the direct current coil is increased, gradually drawing the core downward, thus moving the contact out of engagement, and stopping the rheostat at the approximate correct position for balanced conditions. As the excitation voltage reaches the approximate value required for the given load conditions on the generator, the "inching" process starts in until the final correct alternating voltage is obtained.

Power Transmission By Leather Belting

By J. Edgar Rhoads* and R. R. Tatnall**

TRANSMISSION OF power by belting seems such a simple thing that practically no scientific work has been done until recently in an effort to ascertain what really happens when the belt at a high efficiency, often 98 to 99 per cent, and steadily year after year pulls its load. Few forms of mechanical equipment have required so little attention; few have cost so little in comparison with work performed.

Putting the belt on the pulleys under tension causes the belt to stretch. The stretch is partly elastic, and partly inelastic. The elastic part of the stretch gives the belt a tendency to contract again, thus causing grip or traction on the pulleys which is necessary for transmission of power, and causing also pull on the journals, which means journal-friction with loss of power. The inelastic part of the stretch is due to a slippage of the leather fibres on each other, and this slip is not recovered when the tension is removed. This means slight internal friction, and some slight loss of energy, which appears as heat in the belt.

Some of these forces which we will consider seem to be a comparatively small proportion of the total forces acting on the belt, and yet under certain conditions, as in the case of centrifugal force at high speeds, they may exert a large effect upon the behavior of the belt.

Now start the belt running, but without load. The new features are the effect of stiffness of the belt and effect of centrifugal force. The stiffness of a belt causes internal friction at all points where the belt bends or unbends. This generates heat and means some lost energy. Centrifugal force acts on every particle of leather that is moving in a curved path, as around the pulleys or in the sag. This causes centrifugal tension in the whole belt.

Every particle of belt while going around the arc of the pulleys has a definite tendency, due to centrifugal force, to fly away from the pulley and thus lessen the grip or traction of the belt on the pulley. It is necessary to have a certain tension on the belt to get this tractive effect, which is caused by the grip of the leather on the pulley. Owing to centrifugal force, it is also necessary, especially at high speeds, to increase the initial tension sufficiently to overcome this tendency of the belt to fly away from the pulley.

Centrifugal tension is added to the tension already in the belt, causing it to stretch more and to stand off from the pulleys. This has the effect of not only reducing the traction on the pulleys, but also of reducing journal friction.

At extreme speeds, the centrifugal tension may become equal to, or greater than the original tension, in which case the belt may be seen to stand off from the pulleys, touching them only at the top where its weight is supported. Under these conditions, little or no power can be transmitted.

If no changes are made in the tension except those produced by centrifugal force, at the higher speeds the power begins to fall off rapidly and at extremely high speed, such as 8000 or 9000 ft. per min., no power would be transmitted. It would, of course, be possible to transmit some power at even these excessive speeds by materially increasing the initial tension upon the belt.

Centrifugal effects tend to make the belt keep the same shape it would have at slow speeds; not to make it fly out into a circular shape, or follow around the pulley. This latter effect, where observed, is due to stiffness,—never to centrifugal force.

This can be proven by an experiment with a chain, which is made to rotate at a high speed around a moving pulley, while the chain hangs loose below the pulley, that is, the chain is much longer than the circumference of the pulley. When a high speed is attained, the chain can be pushed sideways off the pulley and it will crawl along the floor, maintaining its same oval shape without forming a circle, though where it actually rests on the floor there is a slight flattening effect. As its energy is lost, it will, of course, collapse.

When a load is applied, the important additional factors are changes in length, creep, and slip.

When transmitting power, there must be a tight and a slack side. A given section of belt is stretched more on the tight side than on the slack side, therefore this section is longer when passing onto the driving pulley than when passing off. The reverse is true at the driven pulley. The change in length must take place while on the pulleys and is called creep.

On account of the elasticity of leather, there is actually a different speed in the particles of belt traveling on the tight side from that which exists on the slack side.

Creep takes place probably in the region which begins at the point where the belt leaves the pulley, and extends backward as the load is increased, finally covering the entire arc of contact. At this point slip begins, that is, in addition to the creep, the belt as a whole be-

*Member J. E. Rhoads & Sons, Chairman Research Committee of the Leather Belting Exchange.
**Experimental Engineer, J. E. Rhoads & Sons.

gins to slip on the pulley all around the arc of contact. Speed of slip increases with increasing load, and when excessive, the belt may run off the pulley.

Two factors in the transmission of power are speed, and pulley traction or grip.

More power may be transmitted by running the belt faster. Except for the centrifugal effect, the power would be proportional to the speed,—twice the speed would give twice the power, but since the unfavorable effect of centrifugal action is proportional to the square of the speed, this soon overbalances the other, and beyond a certain point, power begins to decrease as the speed increases.

Since the centrifugal effect depends on the weight of the belt, it is advantageous to use the lightest stock and the thinnest and narrowest belt compatible with sufficient strength and reasonably long life.

Grip or traction is the frictional force of the pulley on the belt, and is equal to the difference of tension between tight and slack sides. The friction does not depend on the width of the belt, but does involve:—

(a) Character of surface of belt—kind of leather, tanning, currying.

(b) Pulley surface—iron, steel, wood, paper, etc.

(c) Tension of belt, because this produces pressure of belt on pulley; the greater the pressure, the greater the traction.

(d) Arc of contact: the friction increases rapidly with the arc of contact, so that a small increase in arc gives a large increase of friction.

(e) The speed of creep and slip: friction between the belt and pulley increases as the speed of slip or creep increases. In other words, the grip of the belt on the pulley is better when slipping, and the faster the slip the better the grip, up to a certain point. Evidently this must be true, else after slip begins, no more power could be transmitted—the belt would simply slip faster.

This property of leather belting, which gives an increase in its pulling power as the slip increases, is a most interesting and valuable property, and one whose significance has been appreciated only for a short time. It is this property which gives to leather belting, which has been properly tanned and curried, its capacity for carrying enormous overloads above the normal rating of the belt.

Lime Is Basis of Water Treatment for Ice Making

CHEMISTRY OF RAW WATER ICE IS SIMPLE AND ADDS TO KNOWLEDGE OF WHAT IS GOING ON WHEN WATER IS TREATED

DON'T shy at the chemical symbols and equations which are shown in the tabulation which goes with this article. They appear complex and uninteresting, but as a matter of fact you will find them simple and interesting if you have anything to do with treatment of raw water for ice plants. Unfortunately for those who look upon chemistry as a mystic combination of unintelligible symbols, this science has furnished the clue for successful ice making without the use of distilled water. For the practical operation of water treatment, it is not absolutely essential to understand all the why and wherefore but it adds to interest of such work to know why different minerals in solution affect the quality of the ice and how the treatment works.

Water as it passes through various strata of earth and rock has a habit of picking up minerals and gases in solution which may add to the drinking qualities but are apt to cause the engineer a lot of grief when he tries to use the water in a boiler or for the purpose of making ice. Among such minerals, in their various forms, are calcium, magnesium, sodium, iron and silica, while the gases which cause a part of the trouble are dissolved oxygen and carbonic acid gas. Besides these items, there is usually a certain amount of organic matter and countless bacteria, harmless and otherwise.

ANALYSIS DOES NOT SHOW ORIGINAL FORM OF MINERAL

MOST engineers who have had anything to do with water treatment are familiar with the analysis which shows the constituents reduced to the form which are detrimental to ice making. Actually, however, the minerals occur in other forms than those shown in the final analysis. We say water contains carbonates, when as a matter of fact if the water did contain certain of the carbonates, an ordinary filter would take them out. Calcium carbonate, for instance, is insoluble, but the bi-carbonate, which is simply the carbonate held in solution by carbonic acid gas, is soluble. Actually, then, the water contains the bi-carbonate, but during the freezing process the carbonic acid gas is driven off and the carbonate precipitated. Since water in freezing tends to throw off impurities, the precipitate (in this case calcium carbonate) concentrates in the core water. You will recall that salt water freezes at a lower temperature than fresh water. The same thing holds true for a core water containing impurities and if the concentration becomes large the freezing temperature actually drops below 32 deg. F. Hence a longer freezing time is required.

This point is not the Jonah, however, but the fact that the core is larger and has a beautiful dirty color, is the real cause for worry. Housewives prefer to buy ice without this artistic effect.

As previously intimated, calcium or limestone, is the chief mineral which has a usefulness of zero as far as ice making is concerned. It occurs in most cases as calcium bi-carbonate or as the sulphate, although the concentration of sulphate in most water is not apt to be sufficient to cause trouble.

For the treatment of calcium bi-carbonate, lime is the reducing agent and the bi-carbonate is changed to the insoluble carbonate. In other words, the reaction takes place in the water softener instead of in the cake of ice during the process of freezing. The lime is added to the water and the reaction takes place in the sedimentation tank where the carbonate settles out as a white sludge.

This action is just the same as that used in boiler water treatment with which the engineer is more apt to be familiar, since it has been discussed for the past half century. Water treatment for ice work is comparatively new since the method came into fairly general use after 1913. While the general scheme of treatment is the same, certain salts which cause no trouble for boiler work

are fatal to raw water ice if present in sufficient quantities.

Magnesium bi-carbonate the second item shown in the tabulation has much the same effect as calcium and treatment is the same. Underground water, containing carbonic acid gas, coming in contact with magnesium, dissolved this mineral and forms the bi-carbonate. In this soda ash and in the earlier days of water treatment when soda ash was used more than it is now, this point was important. While the treatment reduced the magnesium sulphate to magnesium hydrate which could be precipitated, it also left sodium sulphate. The sodium sulphate was found to be just as bad in its effects on the ice as the original magnesium sulphate. Where lime alone is

EFFECT ON ICE OF VARIOUS MINERALS CONTAINED IN WATER AND HOW THEY ARE ELIMINATED

Minerals in Water and Their Symbols	Effect on Ice if Water is not Treated	React With	Chemical Equation for Reaction
Calcium Bi-carbonate $CaCO_3.H_2CO_3$	Forms gritty, dirty colored deposit in the ice, usually in lower part and center of cakes. Causes shattering at low freezing temperatures	Lime $Ca(OH)_2$	$Ca(HCO_3)_2+Ca(OH)_2=2CaCO_3+2H_2O$
Magnesium Bi-carbonate $MgCO_3.H_2CO_3$	Forms gritty, dirty colored deposit in the ice, gives unclear appearance and also causes shattering at low freezing temperatures	Lime $Ca(OH)_2$	$Mg(HCO_3)_2+Ca(OH)_2=Mg(OH)_2+2CaCO_3+2H_2O$
Magnesium Sulphate $MgSO_4$	Forms opaque greenish or grayish colored cakes, concentrates mostly in cores and retards freezing. Often shows up as white ice and dirty colored streaks, spots and heavy cores	Lime $Ca(OH)_2$ Soda Ash Na_2CO_3	$MgSO_4+Na_2CO_3=MgCO_3+Na_2SO_4$ $MgCO_3+Ca(OH)_2=Mg(HO)_2+CaCO_3$
Magnesium Chloride $MgCl_2$	Same general effect as Magnesium Sulphate	Lime $Ca(OH)_2$ Soda Ash Na_2CO_3.	$MgCl_2+Na_2CO_3=MgCO_3+2NaCl$ $MgCO_3+Ca(OH)_2=Mg(OH)_2+CaCO_3$
Calcium Sulphate $CaSO_4$	Causes white ice, concentrates in the cores and retards freezing but does not form a deposit—Also causes white shell around bottoms of cakes—Not as objectionable as Magnesium Sulphate	Soda Ash Na_2CO_3	$CaSO_4+Na_2CO_3=CaCO_3+Na_2SO_4$
Calcium Chloride $CaCl_2$	Same general effect as Calcium Sulphate	Soda Ash Na_2CO_3	$CaCl_2+Na_2CO_3=CaCO_3+2NaCl$
Sodium Bi-carbonate $Na\ CO_3.H_2CO_3$	In only small quantities this is known to be the cause for shattering at freezing temperature less than 15 deg. F.		Sodium Salts are not removed by lime or soda ash treatment, water with much of these salts present is not suitable for raw water ice. Distillation is the only way to remove sodium salts
Sodium Sulphate Na_2SO_4	Causes white ice, concentrates in the cores and retards freezing but does not form a deposit, causes white shell around bottom of cakes	.....	
Sodium Chloride NaCl	Same general effect as Sodium Sulphate		
Iron Bi-Carbonate $Fe\ CO_3.H_2CO_3$	Causes bad discoloration, yellow or brown deposit	Lime $Ca(OH)_2$	$Fe(HCO_3)_2+Ca(OH)_2=Fe(OH)_2+CaCO_3+CO_2+H_2O.$ $Fe(OH)_2+Air=Fe(OH)_3$
Iron Sulphate $Fe(SO_4)_3$	Same effect as Iron Bi-Carbonate but not as frequently encountered	Lime $Ca(OH)_2$	$Fe(SO_4)_3+Ca(OH)_2=Fe(OH)_3+Ca\ SO_4$
Aluminum Silicate	Is carried in water as finely suspended particles—causes dirty deposit in ice	.....	Must be removed by filtering
Silica SiO_2	Same effect as Aluminum Silicate.	.....	Must be removed by filtering
Organic Matter	Causes discolored cores	.....	Must be removed by filtering

case, however, there is a slight distinction—magnesium carbonate is quite soluble and so an additional amount of hydrated lime is required to precipitate it as insoluble magnesium hydrate.

Magnesium Sulphate Is Hard to Handle

Magnesium sulphate is a mean one to handle if it occurs in any quantity. It reacts with both lime and used for treatment the magnesium sulphate is reduced to calcium sulphate which does not have quite as bad an effect on ice as either magnesium sulphate or sodium sulphate.

When you get to juggling these carbonates, sulphates, chlorides to say nothing of nitrates which have not been included, you begin to get dizzy. The thing to remember is that it is not as bad as it looks or sounds.

Magnesium chloride is the next on the list and this also will have a double reaction if both lime and soda ash are used in the treatment. The magnesium is precipitated as the hydrate but sodium chloride remains. The situation is therefore similar to the trouble with the double treatment of the sulphate; the sodium chloride is worse than the original magnesium chloride.

Both the sulphate and chloride of calcium must be treated with soda ash for their removal; but since sulphate and chloride of sodium are formed, the result will not add to the properties of the water for ice making purposes.

For real trouble, the sodium group is a bad one if present in any concentration. Distillation is the only cure and for that reason the distilled water plant will be found in certain sections of the country where water contains these salts.

Iron Does Not Occur as the Oxide

In the analysis, iron is usually shown as the oxide although ,as a matter of fact, it usually occurs as the bi-carbonate or the sulphate although the sulphate is not so prevalent. On treatment with lime, iron bi-carbonate breaks down into ferrous hydroxide and then as contact with the air takes place, breaks down in ferric hydroxide which is insoluble. When the chemist makes his analysis the residue left after igniting the ferric hydroxide is iron oxide.

Clay is the main source of aluminum silicate and this picked up and carried by the water as a colloidal solution. If you do not recall what a colloidal solution is, it might be explained that such a solution is the one where the particles are carried mechanically in a finely divided state. An ordinary filter will not take out particles as fine as these unless a coagulant is used. This is one reason for the use of alum in a filter. These fine particles have some sort of an affinity for alum and tend to group themselves around the alum particles. We say that the silicate has coagulated. In this condition, the filter removes it without difficulty.

As the oxides of aluminum are highly insoluble, it is probable that the water in its original state never carries this form of the element. No sulphates or carbonates of aluminum are found in water.

Silica or common sand is frequently carried in suspension and must be removed by filtering which also applies to the organic matter.

One phase of the water problem for ice which is seldom touched upon is contamination with sewage. This frequently occurs to some degree and the measure of such contamination is based on the amount of free ammonia and albuminoid ammonia which has been found. The Federal regulation in this regard is that of the health department (which comes under the U. S. Treasury) which places the maximum amount of free ammonia permissible as 0.005 parts per million and of albuminoid ammonia at 0.07 parts per million. The method of treatment for such contamination is the use of chlorine or calcium hypo-chlorite (bleaching powder).

Freezing Does Not Kill All Bacteria

Bugs. as the chemist may fondly call the bacteria, are an important consideration in a water supply and it holds just as true for ice. Certain kinds of bacteria are killed by freezing, but others seem to thrive on it. Typhoid bacteria, for instance, are not particularly discommoded by being forced to occupy a piece of ice as a temporary domicile.

In determining the bacteria count, the dangerous kind are not counted since it seems they are rather difficult to handle in the laboratory. Instead a first cousin, bacteria-coli, is counted. What a flea is to a dog a bacteria-coli is to the regular typhoid bacteria. Where one is found there also resides the other. By taking 100 cc. of the water and making a culture, the chemist raises the bacteria-coli. They grow in colonies and if there are more than two of these colonies per 100 cc. the water is dangerous. Not because the bacteria-coli itself is dangerous, but it indicates that its first cousin the typhoid germ is present in like numbers.

Now that we have considered some of these fundamental reactions what does it all mean? It means that with some water you can make good raw water ice and with others it is practically out of the question.

If the sum of all the sulphates and chlorides is around 30 grains per U. S. gallon, the results will be fair. The water can be treated with some degree of assurance that the ice will b esalable. If in addition the water contains sodium bi-carbonate, then the sum of the sulphates, chlorides and the bi-carbonate should not be over 25 grains per U. S. gallon.

If 40 grains per U. S. gallon is encountered, the propostion is practically hopeless. Distillation is the best bet.

Arc of Contact*

By W. F. Schaphorst

EVERY ONCE in a while we read articles on the transmission of power by belts, in which intricate formulas are used. The writers of the articles seem to like to make belt transmission as complex as possible. Why they do so, I do not know, because as Goldberg, the cartoonist, would say, "It's all wrong, Sir Isaac Newton; it's all wrong." I have conversed with many a belt drive designer of the largest manufacturers in the country and they all pooh-pooh the complex formulas. Occasionally, perhaps, one will meet a theorist who looks on the importance of complex formulas with much seriousness; but I have not run across any of them yet, outside of our colleges.

For instance, theorists like to insert "arc of contact" into their formulas somewhere. I appreciate the fact that arc of contact has much to do with power transmission; but it is not very often that we have to contend with a belt that has much more or less contact than 180 deg. It is generally assumed by drive designers that the arc of contact is about 180 deg., and a sufficiently wide belt is used to allow for the slight difference that might be caused by a smaller or greater contact.

Ninety degrees, for example, is a very rare arc of contact; yet I have seen table after table on the subject of pulleys and belts that start with 90 deg. contact. Then those selfsame tables stop with 180 deg., just as if 180 deg. could be or is the limit of contact. Now, since arcs of contact greater than 180 deg. are common in practice, due to idlers or natural slackness of belts, even though one of the pulleys may be considerably larger than the other, it is plain that there is little cause for worrying about arc of contact on the ordinary or average drive.

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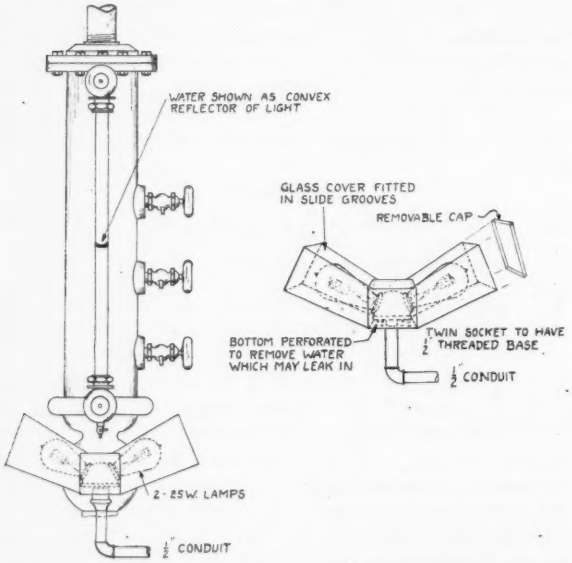
LETTERS DIRECT FROM THE PLANT

Illumination of Water Columns

ILLUMINATION OF the water column, which in many plants is sadly neglected, should be of vital importance to the engineers and also to the firemen or water tender whose duty it is to care for and regulate it.

Having charge of a plant in which the boilers are set high over dutch oven furnaces, I gave the matter considerable thought, especially after one large engine had a narrow escape from being wrecked by water. The fireman gave the excuse that he thought he saw the water level between the first and second gages; but after an investigation of water column after the occurrence, what he thought was the water was a ring of incrustation on the inside of the glass.


WATER SHOWN AS CONVEX REFLECTOR OF LIGHT
GLASS COVER FITTED IN SLIDE GROOVES
REMOVABLE CAP
BOTTOM PERFORATED TO REMOVE WATER WHICH MAY LEAK IN
TWIN SOCKET TO HAVE ½ THREADED BASE
½ CONDUIT
2 - 25 W. LAMPS
½" CONDUIT

REFLECTOR AT BASE OF WATER COLUMN TO ILLUMINATE THE SURFACE WATER

After trying several makes of commercial reflectors and gage glass illuminators, I finally constructed a reflector and illuminator as shown in the accompanying sketch. This reflector and illuminator is composed of a twin socket which may be of any approved make and fitted at base for ½-in. conduit, and incased in sheet metal as shown. The illuminator is placed at the base of the column as shown, from which position light is reflected from the surface of the water, and gives it the appearance of a silvery disk, which may be seen from any part of the boiler room where it is possible to see the column. This disk is formed by the capillary attraction of the water for the glass, and owing to its convex shape as viewed from below, reflects the light in all directions below its surface.

Philadelphia, Pa. JESSE W. HALE.

Improving Return System from Vacuum Heating System

DURING THE past winter the writer took charge of a plant using a vacuum heating system, and one of the things which he encountered in trying to better conditions was an abnormally low feed water temperature, considering the temperature at which the returns were coming back, and the quantity of exhaust available.

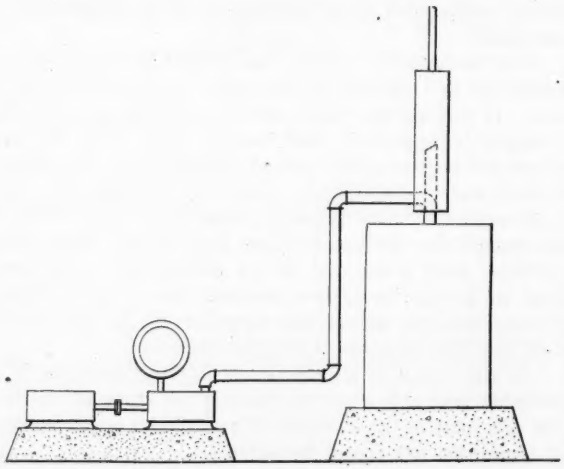


DIAGRAM SHOWING METHOD OF RELIEVING FEED WATER HEATER OF AIR

After checking up these various items, and making an inspection of the heater equipment, it was finally decided that the low temperature was due to the fact that large quantities of air were carried back into the heater with the discharge of returns from the vacuum pump, which returns were emptied into the top of the heater. It was found that a considerable part of the heater was almost inoperative because of the air-logging caused by the presence of this air.

To remedy this, a little stand-pipe was placed above the heater into which the discharge from the vacuum pump was connected, so that the air and gases would have a chance to be liberated through a vent in the top before entering the heater. We found after making this change that a very considerable improvement in temperature was noted, an increase from about 190 deg. to 210 or 212 representing a substantial savings of coal.

Philadelphia, Pa. M. A. SALLER.

Thin Gaskets Make the Better Joint

COMMENTING on the interesting article by Henry Bohmer, Jr., on page 390 of the April 1 number of Power Plant Engineering I would like to say I have had a quarter century experience as chief in fairly large power plants and the result of my experience with flange gaskets is somewhat different from that of Mr. Bohmer, especially as regards reference to thin gaskets. For a permanent, stay tight joint on large flanges, 6 in. pipe and larger, the thinner the gasket on the final tightening of the bolts, the less the danger or possibility of a blowout or a leak. Flange gaskets that will seldom give trouble consist of a piece of 1/32-in. thick sheet asbestos applied wet to machined or faced flanges, and tightened up as snug as safe practice allows. To apply properly, dry out and tighten a thin wet sheet asbestos gasket in a large flange joint, on a high pressure steam pipe, requires care, time, and knowledge, but the results secured as a tight permanent joint will well repay the trouble. It will give better service than that given by much more expensive ones, and as a permanent joint it will be as good as the best, under severe service with frequent expansion and contraction strains The reason such a gasket is not more frequently used by the operating engineer is perhaps on account of the considerable difficulty in handling thin wet sheet asbestos; it is as easy to tear as wet tissue paper. Such gasket can, of course, be used only once; if the nuts are loosened or the flanges separated, a new gasket will have to be used to remake the joint.

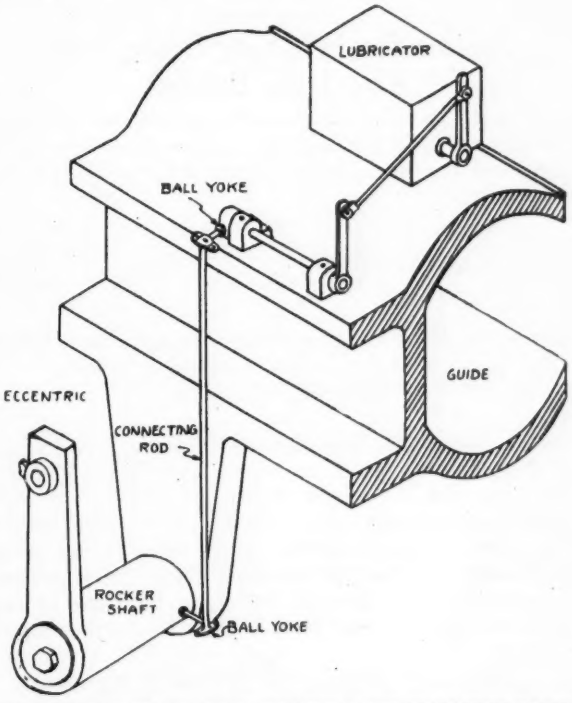
Expansion and contraction must always be provided for by bends, swing joints, slip joints, or a combination of all three, depending upon the variation of the temperatures outside and inside the pipe line, the length of the line, the purpose and the size of the work. A short pipe line of 25 ft. will expand approximately ½ in. in length with a variation in temperature from 60 deg. F. to steam at atmosphere pressure. How many tightened up corrugated flange gaskets would have to be in the line to provide for this small amount of expansion if no other provision to take care of it had been made? My own experience has convinced me that tight flange joints and thin washers on a properly erected steam line is the job which will develop no leaks so long as the flange is not disturbed. JAMES E. NOBLE.

Toronto, Canada.

Making Ford Parts Useful Around a Steam Engine

IN INSTALLING a force feed lubricator on a Corliss engine, the driving motion had to be taken from the valve rocker shaft at right angles to, and below the working position of the lubricator. This arrangement required a connection between two oscillating shafts at right angles, one above the other. A connecting rod with plain end bearings could not be used, as each bearing moved in two directions due to the angular motion around the shaft; neither could the position of the lubricator be changed to get a straight line drive, due to the necessity for having a well-lighted location and to avoid interference with other working parts.

By using the steering gear connecting rod and two spindle connecting rod yoke balls from a Ford steering gear assembly, the installation was made as shown in the accompanying sketch. The valve rocker shaft and the collar on the jack shaft were drilled and tapped for the yoke balls and the connecting rod was heated and the ends twisted to line up with them. A little filing was necessary on the caps to give clearance for the balls at the extreme position of the stroke and new oil holes had to be drilled for lubrication. The connecting rod was then placed directly on the ball yokes and the lubricator started in operation.



DRIVE FOR MECHANICAL LUBRICATOR MADE FROM FORD PARTS

Since its installation, this drive has given perfect service and the cost and amount of time required for fitting the standard Ford parts was much less than if two ball joints or universals had been made especially for the job.

Philadelphia, Pa. N. C. BYE.

Babbiting a Valve Disc

IN THE April 15 issue of Power Plant Engineering, there appears an article on filling worn valve discs with babbit, which brings to my mind an experience I once had in repairing leaky blowoff valves.

Originally the discs were filled with fiber which had become worn so I decided to fill them with babbit. Instead of being cored out around the outside edge, so as to form a ring of filling, the center had been cored out so that it made a solid filling about 2 in. in diameter by about ¼ in. thick. The discs were filled with babbit, which made a good tight valve, and everything went lovely for a while; but finally, one morning, the night fireman reported that he could not blow down two of the boilers. He said that the valves would open all right, but nothing would come through the blowoff line.

The valves were of the angle type and had been installed so that the pressure came on top of the disc, and when the bonnets were removed it was found that

the babbit filling had become loose and dropped out of the disc and remained on the seat.

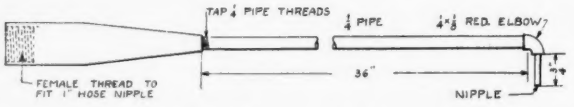
To overcome this difficulty, I had a hole drilled in the center of the disc, and tapped for a ⅜-in. cap screw. When they were refilled, the cap screw was put in with a washer on it, and a space left between the washer and disc, which was filled with the babbit.

This prevented the filling from coming out and no more trouble was experienced.

Lowell, Mass. E. C. WELLS.

Device for Washing Scale from Fire-Tube Boilers

WHERE IT is impossible to reach with an ordinary straight nozzle in washing out a horizontal return tubular boiler, the special nozzle shown in the accompanying



BOILER WASHING DEVICE CONSISTS OF REDUCING A SHORT LENGTH OF ¼-IN. PIPE, A REDUCING ELBOW, AND A ⅛-IN. NIPPLE

sketch may be used to advantage. The cost is practically nothing and the results are surely surprising. The first time we used it, we got two 16-qt. pails full of scale after we had washed all we could with a straight nozzle. The nozzle is run down between the tubes, turned crosswise and then dragged back and forth like a scraper. I have washed off pieces of scale ¼ in. thick and as long as 5 ft. where no scale could be seen from either top or bottom.

Minneapolis, Minn. FRED S. RUTLEDGE.

Installation and Operation of Non-Return Valves

IT WOULD seem that if we wish to follow present engineering practice, the non-return valve should be placed as near the boiler as convenience will permit, with no other valve between it and the boiler.

In cutting a boiler in or out this valve may be disregarded, as it will open or close of its own accord as the pressure in the boiler becomes greater or less than that in the header.

When a boiler is cut out for cleaning, the header stop should be closed as a precaution of safety to those who have to work in the boiler.

When starting up, the non-return will float open as soon as sufficient pressure has been built up in the boiler to overcome the weight of the valve and dashpot pistons. A drain should be located on the boiler side of the header stop valve; this drain should be left open while bringing the boiler up to the working pressure. This will allow steam to pass through, and warm up the entire length of pipe gradually and uniformly, and at the same time flow all water and foreign matter from the pipe until it is ready to be put in service.

I know of no reason why two stop valves should not be operated in the same way, as one stop and a non-return. This is the custom followed by the engineers of three modern plants which were put into service in 1922 and 1923; but as regards the installation of the non-return, my judgment is different and when it's my turn to design a boiler plant I will place a good reliable stop valve between the boiler and non-return.

I had a non-return become balky one morning after about 6 mo. perfect operation. This valve was on a waste heat boiler used in connection with a gas producer to reclaim the waste heat from the gas.

This non-return absolutely refused to open, so the steam started a row with the safety valves which continued for more than an hour, during which time we had all sorts of professors and tradesmen trying their hands at opening this valve. In fact, there was such a crowd of managers, superintendents, master mechanics, designing and other engineers of professional rank that there was little room left for the operating man. The hand wheel was run down and up until much of the paint was worn away and many hands were blistered. The pilot line was tried again and again without success, so finally the chief ordered the boiler cut out and the valve replaced with a new one.

In this case there was no spare or emergency boiler to be used so the entire unit had to be shut down. When the boiler had cooled sufficiently, the bonnet was removed from the non-return valve and nothing found wrong except the little relief port in the upper dashpot piston was plugged with scale and corrosion. Much argument ensued as to whether this was sufficient cause for the action of the valve and it was agreed to give the old valve another trial. That was the last trouble that valve had given when I left the plant a year later. That repair could have been effected in 30 min. if there had been a stop valve between the boiler and non-return. As it was, 10 hr. were consumed and the total gas production of that plant is two million cubic feet less than it might have been.

Kearny, N. J. L. H. FLOYD.

Heating Water With Live Steam Proves Economical

SOME YEARS ago, a concern used a sectional cast-iron house heating boiler to heat a large quantity of water for washing, cooking, and other domestic purposes. Steam boilers carrying 20 lb. pressure were in use in the building, but there was no exhaust steam available for water heating. The owners were told that the water heating could be done at a lower cost by using live steam instead of the separate boilers, but they insisted that the fuel used to generate live steam would equal that used in the cast-iron boilers.

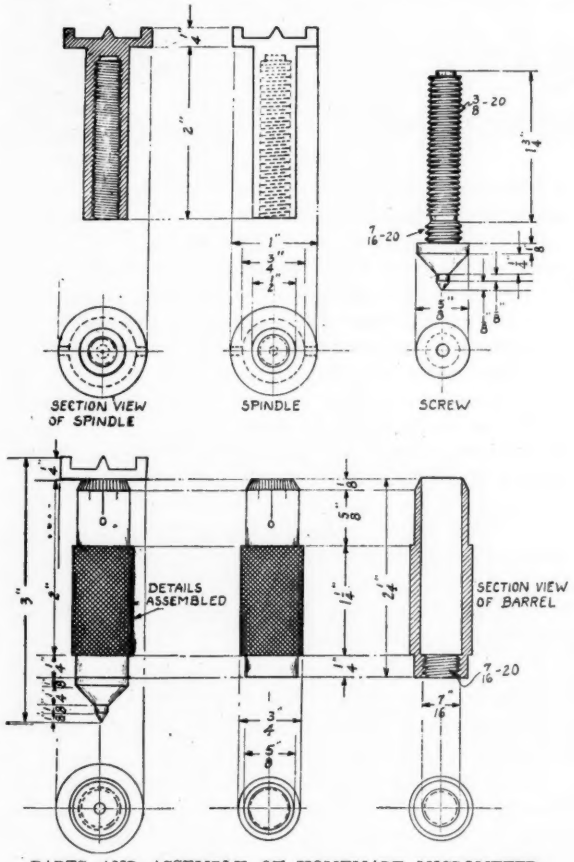
Ultimately a temporary plan was tried out by installing a mixing valve in the open hot water tank. The result was that the water was maintained at a high temperature at considerable less labor cost, as only one boiler had to be fired, cleaned, etc., and the combined fuel saving amounted to nearly 2 T. a week.

Toronto, Ont. JAMES E. NOBLE.

Homemade Inside Micrometer

SOME TIME ago, my superintendent asked me to measure the cylinders of a gas engine. I had no inside micrometer nor could I borrow one, so I turned one up on the lathe according to the accompanying drawings. I divided the chuck of an old Davis and Pond lathe into

50 equal parts so as to get the scale on the barrel. The only taps I had were a ⅜-in.—20 and a 7/16-in.—20. One full turn is therefore 0.05 in. and every division



PARTS AND ASSEMBLY OF HOMEMADE MICROMETER

on the barrel scale is 0.001 in. The drawings illustrate how the various parts were made.

Concord Junction, Mass. G. E. JENSEN.

Some Handy Kinks

MOST ENGINEERS, I find, appreciate all kinds of little kinks that tend to make their sundry jobs easier to accomplish or better when done, but for some reason, best known to themselves, do not collect them in written form, preferring to remember them. I have a book of unusual kinks, most of which I secured from various engineers while on the road as an inspector. Few had these kinks written up but many were able to tell about them if they were so inclined.

Dozens of times engineers have shown me easier ways of doing things, methods they had doped out themselves for jobs that I had previously done in the hardest possible way. I have visited plants and found the operators doing work that they made a big job of, while in other plants the same job was considered a small affair, and I noted that where the job was easy the engineer had figured out some method of his own for doing it. He had worked out a kink.

Nothing interests me more than to look over some old timer's note book. I have picked up hundreds of ways of doing things, not common knowledge, things told in the language of the man on the job.

In the following I am giving some of the data I've picked up and thought worth keeping.

As a general thing, fire brick is costly and in cutting this brick there is generally a big loss. A simple method and one that means no lost bricks is to use a saw for the cutting. A buck saw is the proper tool for this work.

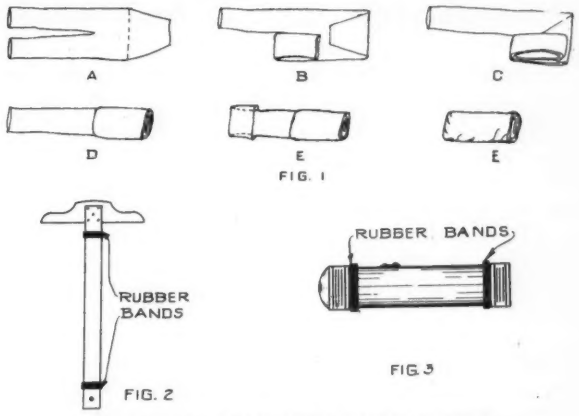


FIG. 1 FIG. 2 FIG. 3

THESE IDEAS HAVE BEEN FOUND USEFUL

IN FIG. 1. a simple and neat method of folding overalls is shown.

(a) Overalls laid out on floor.
(b) Right leg folded at knee and bib turned down.
(c) Right leg folded to top.
(d) Right leg folded over on to upper part of left leg.
(e) Left leg turned inside out and brought up over right leg.
(f) The finished parcel.

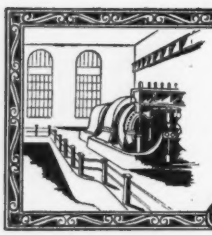
In doing fine work with a T-square it sometimes happens that the square slips, without the worker knowing it. This slip can be prevented by placing wide rubber bands on each end of the rule. See Fig. 2.

Drilling lead would appear to be a simple matter but those who have tried it are generally not satisfied with the holes as made. In making holes in lead flood the drill with a good grade of lard oil. With thick plates lift the drill often and clean it. A drill speed of 800 to 1000 r.p.m. is found to give good results.

Some time ago I bought an all-metal case, electric flash lamp. In working, I laid the lamp on a steel floor and it short-circuited and burned the batteries out. Shortly after, in talking with an old engineer I mentioned my trouble and he showed me a kink of his own, which eliminated the chance of this happening. He had two rubber bands on the battery, as in Fig. 3.

ARTHUR D. PALMER.

GENERAL lubricating value of greases is only as good as the oil from which they are made, since they are reduced to fluids when in the journal. Greases are wasteful in power and for the same lubricating value are more expensive than the fluid oils. It is often thought that greases are economical because they are consumed slower. Since the value of the grease is only the oil it contains, if proper oil feeding devices are used, oils will be found from 10 to 15 per cent more economical in cost and many times more economical in power loss.



PROBLEMS IN OPERATING POWER EQUIPMENT

Design of an Ice Freezing Tank

ON PAGE 445 of the April 15 number of Power Plant Engineering, a design for an ice freezing tank is given, which reminds me of trouble that one large concern had with its tank because of the fact that it was allowed to rest flat upon the ground.

After the tank had been in use for a year or so, it was discovered that the ice cans did not fit properly and that the bottom of the tank was rough. The bottom was concreted on top of the ground and then immediately on top of the concrete came the timbers, the filling between the timbers, the pitch, air spaces, etc., and lastly the steel tank itself. This was considered very good construction by the refrigerating engineer who put it in, and to most engineers it would probably have looked good.

It was decided after the tank had been in use for several years that the unevenness of the bottom of the tank was due to the upheaval of the ground beneath the tank. Some of the officials thought the upheaving was due to the difference in temperature between the tank and the ground, however, the real reason was likely due to the fact that the plant was located on rather low ground and that the ground was moist. During the winter time, the alternate freezing and thawing of the ground possibly is what caused the unevenness and consequently the trouble with the ice cans.

In building a new tank 3 yr. ago, an air space was allowed between the lower timbers of the tank and the concrete bottom, which allows the ground to vary as much as it chooses and the tank will maintain an even bottom. In order to avoid air currents beneath the tank, to reduce radiation or convection losses as much as possible, the outer edge was entirely sealed, locking the air beneath the tank. No unevenness whatever has yet been discovered in the new tank.

Newark, N. J. N. G. NEAR.

Steam Engine Operator's Questions

THE QUESTIONS which I submit herewith are ones that have presented themselves to me recently in the course of my work. Will you kindly answer them for me?

1. When operating a slide valve engine with direct valve gear, and the valve is properly set, what effect will the lengthening of the eccentric rod have on the steam distribution in the cylinder?

2. What is the object of having sharp edges on piston rings?

3. When it is found that the low pressure cylinder of a cross compound engine is doing more work than the high, what steps should be taken to correct the condition?

4. What care must be taken in adjusting an automatic governor for a change in speed?

5. What effect will slow action of the dashpot on a Corliss engine have on the steam? W. H.

A. Lengthening the eccentric rod on a slide valve engine would move the valve toward the head end of the cylinder, which would have the effect of giving more steam lap on the head end and less on the crank end, less exhaust lap on the head end and more on the crank end. The result of this on the vents in the head end of the cylinder would be to retard admission and compression and advance cutoff and release. On the crank end the effect would be reversed; admission and compression would be advanced and cutoff and release would occur later in the stroke.

2. Sharp edges on piston rings are for the purpose of providing contact with the cylinder wall at the edge of the ring. This prevents access of the steam pressure to the outside of the ring, which would ten to force the ring inward and permit leakage.

3. If the low pressure cylinder is doing more work than the high, the remedy is to reduce receiver pressure by decreasing the cutoff in the high pressure cylinder and increase it on the low pressure side.

4. Before any change is made in the governor setting to increase the speed of the engine, a calculation should be made to see that the additional speed will not increase the rim speed of the flywheel beyond the safe limit. For ordinary cast-iron flywheels, the rim speed, for safe operation, should not exceed about 100 ft. per sec.

5. Slow action of the dashpot on a Corliss engine will cause a slow closing of the steam valve which will result in wire drawing of the steam through the port. This action is accompanied by a loss of available energy and should therefore be reduced to a minimum by speeding up the movement of the valve at the moment it closes the port.

Comments on Indicator Cards

IN THE April 15 issue, on page 444, indicator diagrams are submitted by C. M. S. for comment. One pair was taken when the engine was pounding, the other when the engine was running quiet. If his engine has two eccentrics, I would suggest that he move the exhaust eccentric ahead in the direction of rotation. This would give more compression, but also an earlier exhaust opening. If the engine has one eccentric only, move this ahead, but lengthen the steam rods, and shorten the dashpot rods enough to compensate. Card No. 1 shows a late exhaust opening, but the compression seems to be sufficient. After the exhaust radial rods are lengthened, the exhaust opening will be still later. Sometimes an engine will require considerable compression to make it run quiet, and it sometimes needs more at one end than at the other. This is, however, a comparatively slow

speed and will not require as much as if it ran over 100 r.p.m.

This pound may also occur from end play of the exhaust valves; draw the key of the valve lever, and drive stem and valve back, taking up the lost motion with the collar on the valve stem, or with whatever means that is provided. Another way to take up lost motion is to put shims between the bonnet and the end of the valve. This noise will travel over the engine and appear to come from different places.

It might be that the crosshead pin is worn and a ridge left on the top where the brasses rock back and forth. I have known this to cause a baffling knock. If the packing on the piston rod is of the floating ring type, contained in a case in the stuffing box, it may be loose; tighten up the gland. Again the piston may be loose on the rod, or the rod loose in the crosshead.

Burlington, Ia. TOM JONES.

J. M. B., ON PAGE 444 of the April 15 issue, asks for the opinions of readers relative to the indicator diagrams from his low pressure cylinder. It would have been better had he sent in simultaneous diagrams from both cylinders, thus telling the whole story. As it is at present, there is not much to go by other than the shape and outlines of the diagrams, and the data that he gives. The diagrams seem to show a much overloaded engine, as judged by the high release pressure. Of course much depends upon the type of valve and gear involved, of which nothing is said in the letter. The cylinder ratio seems to require a higher receiver pressure than that used at present, something in the neighborhood of 25 lb. at least. This may perhaps be obtained by an earlier cutoff in the low pressure cylinder, which would build up a higher back pressure in the high pressure cylinder, but would also transfer more load to the low pressure, with a lower terminal pressure, and a greater efficiency than at present.

If J. M. B. would send in a set of diagrams from both cylinders, with the atmospheric lines drawn in as should always be done, and tell the type of valves and gear the engine is equipped with, then a much more satisfactory opinion could be given.

Brooklyn, N. Y. CHARLES J. MASON.

Amount of Coal Required for Heating

HOW MAY I calculate the amount of coal that should be charged against a given number of square feet of direct coal radiation? The coil in question contains 1475 sq. ft. of surface and the boiler supplying it steam has an efficiency of 65 per cent. L. B.

A. The amount of coal that can be charged against a given amount of heating surface will depend upon the rate of heat transmission from the surface which in turn depends upon the temperature involved and the co-efficient of heat transmission. Under ordinary conditions, this coefficient in B.t.u. per square foot of surface per degree difference in temperature between the steam and the surrounding air, per hour will vary from 1 1/5 to 2½ depending on the arrangement and location of the coils, character of the surface, etc. An average value may be taken at about 2. If we assume a steam pressure of 2 lb. gage, the temperature will be 219 deg. F. and if we take the air temperature at 70 deg., the difference will be $219 - 70 = 149$ deg. and the heat transmitted will be $2 \times 149 \times 1475 =$ approximately 440,000 B.t.u. per hr.

With a boiler efficiency of 65 per cent, there will have to be $440{,}000 \div 0.65 = 677{,}000$ B.t.u. per hr. supplied by the coal. For coal having an assumed heating value of 13,000 B.t.u. per lb., these would require $677{,}000 \div 13{,}000 = 52$ lb. per hr.

Design of Piston Rods

WILL YOU inform me how the strength of the piston rod on a steam engine should be calculated? This question was recently asked me by an examining board for an engineer's license. A. W.

A. Piston rods are figured as columns with both ends guided for which the Gordon-Rankine equation applies. In its usual form this equation is

$$P = [S_c A] \div [1 + 4k L^2 \div A]$$

Where P is the thrust along the rod, S_c is the allowable compression stress, k, a constant which for steel may be taken as 0.00033, L, the length in inches, and A, the area of cross section in square inches.

Assuming $S_c \div 5000$ lb., and calling the ratio of the length to the diameter, d, of the rod, n, we may rewrite and transpose the equation so that we may solve for d, the rod diameter

$$d = \sqrt{(1 + n^2 \div 750) \div 5000} \times D \times \sqrt{p}$$

In this equation p is the maximum steam pressure in the cylinder and D is the diameter of the piston.

It will be noted that any value of d which may be found from this equation will depend upon the value of n which involves d directly. In solving this equation, the method then is to assume a value for n, which ordinarily will range from about 8 to 15, and then solve for d. The value thus found should be divided into the length L to see if it gives the value of n which was assumed. If it does not, take another value for n and solve again for d.

An example will perhaps illustrate the method to better advantage. Suppose we wish to find what the diameter of the piston rod should be on an engine having a 20-in. diameter piston and a 40-in. rod where the initial pressure is 150 lb. Assume first, $n = 12$, then

$$d = \sqrt{(1 + 144 \div 750) \div 5000} \times 20 \times \sqrt{150}$$
$$= 0.0154 \times 20 \times 12.25 = 3.78 \text{ in.}$$

Now $40 \div 3.78 = 10.55$ from which we see that n was taken too high. Assume now $n = 10.5$, then

$$d = \sqrt{(1 + 110 \div 750) \div 5000} \times 245 =$$
$$0.0151 \times 245 = 3.70 \text{ in.}$$

The length $40 \div 3.70 = 10.8$, which shows that the choice of n was too low. Take $n = 10.65$ say, then

$$d = \sqrt{(1 + 114 \div 750) \div 5000} \times 245 =$$
$$0.0152 \times 242 = 3.72$$

Now $40 \div 10.65 = 3.74$, hence the last assumption was approximately correct and we may make the rod diameter 3.72 in.

Steam Cylinder Lubrication

IS THERE any rule by which to determine the amount of oil to be fed into an engine cylinder? We have an old 11 by 16-in. engine running at 200 r.p.m.; steam pressure, 100 lb. gage. A. H.

A. On an engine of the size and under the conditions you refer to, we suggest using about 3 drops of oil per minute. Use the least amount you can without having the engine show signs of distress.

POWER PLANT ENGINEERING

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Combined Water Supply and Power Development

One of the most important factors in modern city life is the provision of an abundant supply of pure water for domestic and industrial use. For any particular city, the nature of the water supply will depend, of course, upon the existing possible sources of supply and upon the expense necessary to make such possible sources available. Those cities adjacent to large bodies of pure, fresh water such as the Great Lakes, are fortunate in this respect, and as a rule their water supply problem is solved by the construction of suitable intake tunnels and pumping stations.

Cities on the coast, however, such as New York City or Boston, are obliged to go a comparatively long distance for their supply of water, and the problem becomes more difficult. Thus, New York City has had to build a costly tunnel in order to bring water over a hundred miles from the Adirondacks.

Up to the present time, the water supply for the city of San Francisco has been obtained from a local reservoir and this supply will be adequate for some time to come. In city planning, however, one must look far into the future, and the city of San Francisco, therefore, is planning to bring its future water some 200 mi. from the Sierras. As regard distance, this project is similar to that now used by New York City but it has an additional feature which should be of interest to every engineer who has the conservation of the nation's resources at heart.

This is the power development which will go hand in hand with the water supply project. In fact, it will precede it, and in this manner, the electric power obtained from the carrying out of the power project will allow an immediate income from the property, and thus pay for future construction of the water supply project.

Details of this combination water supply and power development are fully described by Mr. Copley in the leading article of this issue, which is of interest both from an engineering as well as economic viewpoint.

Advanced Ideas in Station Practice Shown in New Plant

In these days of rapid developments in power plant design with rumors of 1200-lb. boilers and 150,000-kw. turbines, plans for a new station must be of a rather startling nature in order to attract widespread attention. The new plant of the Consumers Power Co., now building near Saginaw, Mich., meets fully this competition for a place in the sun.

Plans for this station, which are presented in the news pages of this issue, incorporate ideas which are, in a way, almost revolutionary. For instance, it is proposed to bleed steam from the lower stages of the turbines, to preheat the combustion air. In addition, it is planned to use bleeder steam for feed water heating and for evaporation of make-up. At first thought, this sounds like robbing Peter to pay Paul; but no doubt a consideration of the entire problem of heat balance, including also the possible reduction in size of the low pressure end of the turbines and the use of smaller condensers, has shown that it will pay its way.

Another interesting development which will be tried out is an adaptation of the scheme used in the radiation

type superheater. The main portions of the furnace will be lined with cast-iron blocks which will enclose steel tubes; these tubes to take water from one of the main drums, thus cooling the furnace lining and at the same time adding to the total heating surface.

Ashes will be handled hydraulically even to the extent of pumping 8-in. clinker through manganese lined pumps. There will also be a novel scheme of variable speed alternating current motor drive for the draft fans.

It is evident that the designers of this plant have boldly attacked some of the more advanced and refined problems of station practice with a viewpoint toward corralling the elusive B.t.u. wherever it may be found. Operating difficulties encountered and efficiencies obtained will be watched with interest by all power plant men, as indicative of the value of some of these practices.

Off Duty

The first assistant weather controller sat at his desk in his spacious office at the U. S. Weather Bureau, leisurely examining the weather schedule for the coming week. The afternoon was warm and, apparently, he found little of interest in the report before him,—he yawned, lazily.

Suddenly, however, his manner changed, and he became intent in examining the item on the schedule which had arrested his attention. He studied the record critically for a few moments but his manner was unrelieved. Something obviously was wrong.

"Why, it's impossible," he muttered, "Allen certainly can not have done this intentionally. He must have made a mistake. I'll call him in."

Reaching out to the corner of his desk, he touched one of six electric push buttons and waited.

Two minutes later, the door of his office opened, and a bright looking young man entered the room.

"Did you wish to see me, Mr. Hopkins?" he asked.

"Yes, Allen, I did," answered the older man. "I have been looking over this schedule which you made out for next week and I note here that you have ordered a shower for three o'clock next Wednesday afternoon. Did you do that intentionally?"

"Yes, I did, sir," replied Allen, regarding his chief with an inquiring expression.

"But, certainly, you knew that the White Sox are to play here that afternoon, didn't you?" demanded the first assistant controller rather severely.

"I knew that, Mr. Hopkins, but—," his reply, however, was interrupted by the impatient demand of his chief.

"Then why did you order rain? Don't you know that we have arranged with the baseball teams to give them fair weather when they play here?"

"I am fully aware of that fact, sir," replied the young man, somewhat annoyed, "but the Mayor called me up the other day and asked me to provide clear weather Wednesday morning for the dedication of the new stadium. As we had rain scheduled for that morning, and as Government regulation No. 364A calls for rain in a city of over two million people some time between the hours of 9 a. m. and 5 p. m. on the last Wednesday of the month, I made arrangements with the manager of the White Sox to postpone the Chicago game until Thursday ————."

Not in these exact words, perhaps, but in some such manner will our weather prophets deliberately discuss and plan our future weather supply when L. Francis Warren's scheme of breaking up clouds and "rain making" is put into working.

"Rain Making!" you exclaim and immediately recall to mind a thousand and one other sensational stories of rain making, none of which ever had a more stable foundation than a three-legged calf. You take no stock in accounts of rain making, you say.

But let us reassure you; the case we have reference to is no "get rich quick" scheme dependent upon the proper utterance of three mysterious words or does it entail the use of divining rods or allied paraphernalia. This method, on the other hand, is built upon a firm scientific foundation, and while no rain has yet been made, the next few months may see the actual performance of this thing which has plagued the inventors for ages. The U. S. Army Air Service is planning a thorough investigation of Mr. Warren's plan and experiments have been in progress at the McCook field in Dayton, Ohio.

This process of making rain and dispelling fogs is simple in principle and was described briefly in Industrial and Engineering Chemistry. Two colliding drops of water suspended in air will not run together to make one larger drop unless the impact is very severe because there is a film of condensed air around each drop which keeps them from coming in actual contact. If these films are electrified slightly, however, with unlike charges, the films of air are removed and the drops coalesce.

Clouds consist of myriads of drops of water, each so small that its rate of fall is negligible. Mr. Warren believes that all of these are charged either positively or negatively depending upon conditions. It is probable, however, that this is not always true and that some drops are not charged at all. Whether this is true or not, however, is only of academic interest because the same treatment will precipitate both types of drops.

Now, it is obviously a rather difficult matter to go up to a cloud and strike the drops therein with a stick of electrified sealing wax or to use usual methods of applying a charge. Instead of that, Mr. Warren runs dry sand which will pass a 150-mesh sieve through a nozzle, which was designed by Professor Chaffee of the Cruft High Tension Laboratory of Harvard, and which charges the sand particles to 15,000 v. or higher. Both the sand and electric generator are carried on an airplane 500 ft. or so above the cloud. The operator starts the generator, and opens the hopper, letting the electrified sand run out above the cloud and settle upon it, not the easiest thing in the world to do with a plane flying 110 mi. an hour. That means about one minute for a cloud two miles long, so that it is fair to assume that much of the sand misses the clouds. The skill of the army pilots is so great, however, that at McCook Field at Dayton, it has been possible to smash large clouds to pieces in less than ten minutes.

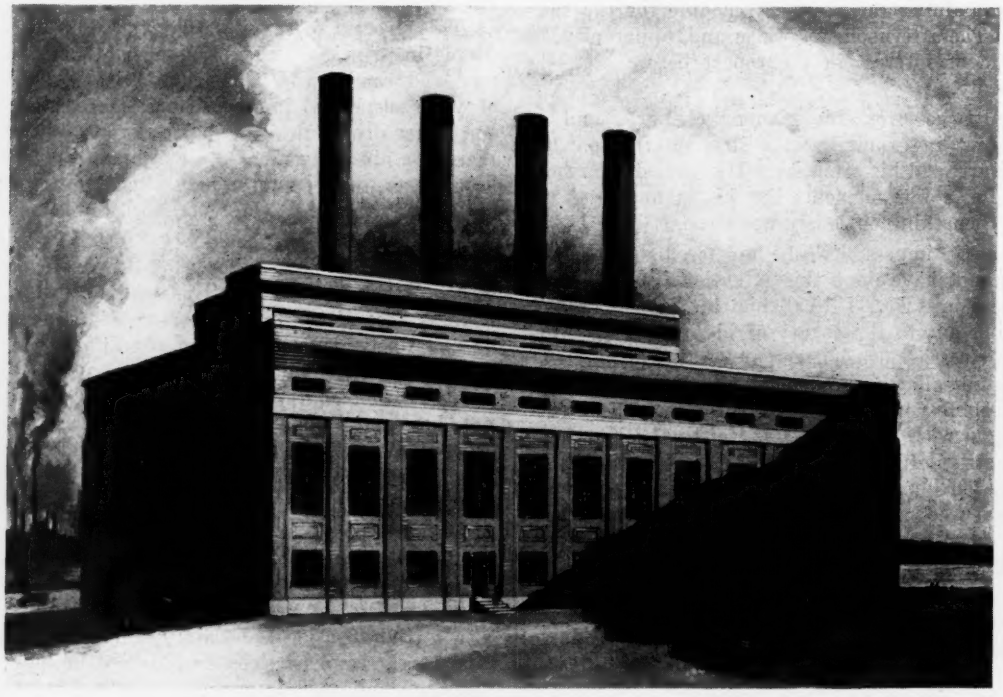
But the clouds at Dayton are no good, Mr. Warren declares. His complaint is that they are thin, emaciated and contain only a small percentage of moisture. Thus, while it has been possible to dispel them they have been found worthless for making rain.

Indeed, things have come to a pretty pass when men thus adversely criticize the "down of the heavens."

Novel Features in Consumers Power Co. Plant

CAST IRON FURNACE LINING; ASHES HANDLED BY PUMPS; AIR PREHEATING BY BLEEDER STEAM; AND BLEEDER STEAM FOR EVAPORATION ARE UNUSUAL POINTS

NEAR Saginaw, Mich., at a little town called Zilwaukee, the Consumers Power Co. has started construction work on a 100,000-kw. steam plant which will have some quite unusual design features. Besides the use of steel heating surfaces protected by cast-iron blocks for the furnace walls and the use of ash sluices and pumps for ash disposal, the station will also have a special arrangement of air preheating and feed water heating. It is expected, therefore, that the plant will generate on a very low heat consumption, obtaining better results than any plant has up to date in the way of fuel economy. Initial installation consisting of two 20,100-kw., General Electric steam turbines will be made within the next 12 mo. It is expected that the first unit will be started up about Dec. 1 and the second unit in March, 1924.



ADVANCE PRACTICE SHOWN IN PLANS FOR THIS STATION

There will be two boiler units to each turbine unit. The boilers will be fired by underfeed stokers of a hydraulically driven type, which will have double roll clinker crushers. Each boiler will have above it a double bank of vertically baffled cast-iron economizers. The superheaters of the radiation type will be installed in the back walls of the furnaces. The boilers will be built for working pressure of 375 lb. gage, and the steam will be superheated approximately 250 deg. F.

WATER COOLED FURNACE LINING

AS PREVIOUSLY mentioned, an interesting feature of this plant will be the substituting of steel heating surfaces protected with cast-iron blocks for considerable parts of the furnace linings, thus doing away with the furnace brickwork. These cast-iron heating surfaces are being supplied by the Power Specialty Co. They are made up of steel tubes running through what will be in effect cast-iron bricks taking the place of fire brick and being watercooled. The water will circulate to a steam drum and will be under the same pressure as the boiler. It is expected that these water cooled furnace linings will

generate steam to correspond to a rate of heat absorption of 60,000 to 80,000 B.t.u. per sq. ft. of exposed surface per hour. Hence, it will be appreciated that water cooled furnace walls will add a considerable amount of steaming capacity to the boilers.

As the power plant will be located nearly 800 ft. from the river, long intake and discharge ducts for circulating water will be required. A concrete intake house with Chain Belt Co. intake screens will also accommodate the circulating water pumps. There will be two 22,000-g.p.m. and one 35,000-g.p.m. pumps to take care of the first two condensers. The condensers will be of the pear-shape variety and built for one pass only with ¾-in. tubes. Condensers will have air cooler sections made up of cast-iron surfaces and the condensers will be of the divided water box pattern so that half of the condenser can be cleaned while the other half is in use. On account of the extensive use of steam for preheating feed water and air, condensers do not need to be very large in this plant.

Make-up water will be purified by means of Griscom-Russell evaporators connected between the bleeders on the 8th and 11th stages of the General Electric turbines. There will be one evaporator to each turbine, having a maximum capacity of 10,000 lb. per hr. A very large storage reservoir for condensate will be provided between the foundation walls under the boiler room basement. This arrangement of evaporators, taking steam as it does from the 8th stage and delivering its vapor to the 11th stage bleeder pipe, eliminates a number of pumps and other auxiliaries that will generally be found with low pressure evaporator plants. In this case, the evaporator feed pump is also to be eliminated, as the water will feed to the evaporators by gravity from the household water service supply tanks. Reaeration of feed water will be accomplished by a very simple and inexpensive way by admitting all condensate that has been exposed to the air in storage back into the system through the main condensers, which will have hot wells of special design and which will deliver condensate practically free from dissolved air and at a temperature higher than that corresponding to the pressure of the vapor in the condenser.

Air Will Be Preheated to 250 or 300 Deg. F.

Air for combustion will be admitted to the building through louvres and heaters in the top of the boiler house and drawn down through ducts carrying with it waste heat from boiler room radiation losses into the forced draft fan room. After passing through the fans on the way to the stoker wind boxes, the air will be preheated by means of hot water and steam bled from the main units to a temperature of 250 deg. to 300 deg. F.

Ash handling system is also of interest, as the ashes are ground through the clinker crushers of the stokers and drop on to secondary grates, which can be dumped by hand into a concrete sluice way which is supplied with water from the circulating system of the main condensers. The ashes will be carried hydraulically to a well, from which they will be raised by motor-operated manganese lined dredging pumps to a wooden launder, which will in turn carry the ashes mixed with water over an extensive piece of territory which will require a good many years to fill in to the desired depth. Pumps will be capable of handling lumps of clinker up to 8 in. in diameter. Pump suction will be protected from larger chunks by a grizzly or grating placed horizontally, on which a considerable number of large clinkers can collect without clogging operations. Such clinkers would be the result of poor operation of the stoker clinker grinders. These large clinkers will probably occur only very infrequently. It is expected that they will have to be broken by hand so they will drop through the grizzly.

Special Drive for Draft Fans

What is believed to be an original arrangement of motors and controls for the forced and induced draft fans has been developed for use at this station. For the forced draft fans a 25-hp., 720-r.p.m. motor and a 100-hp., 1200-r.p.m. motor are direct connected on the same shaft with the fan. These are 440-v., alternating current, slip ring type motors with the 720-r.p.m. motor designed for safe overspeed. Each motor has its controller, which is of the motor operated drum variety, and the controllers are so connected and interlocked that by the mere operation of one push and pull switch on the boiler control board, any fan speed from 360 r.p.m. to 1200 r.p.m. can be obtained. When the drum controller of the small motor has reached its top speed, a contactor automatically cuts this motor off the power supply and another contactor connects the larger motor, and its controller will then accelerate on up to the maximum speed with the small motor merely coasting.

The induced draft fan is driven by a 40-hp. and a 150-hp. motor connected similarly, the 40-hp. motor being connected by a chain drive, while the large motor is direct connected to the fan shaft.

This makes for extreme simplicity of control as far as the operator is concerned, and in addition provides for considerable economy of operation, especially when it is considered that the small motors will furnish the necessary draft most of the time, the large motors being called upon only when the boilers are operated at the very highest ratings. This construction gets away from the necessity of d.c. power in the station and avoids using the brush shifting type of motor, while the efficiency and speed range is much more than is usually obtained by means of slip ring motors.

Quite an extensive acreage of land along the bank of the Saginaw River at the site of this plant is owned by the Consumers Power Co. The Saginaw River is navigable and coal may be received in the future by boat; however, for the present, coal will be received by rail over the Grand Trunk and Michigan Central railroads, both of which have sidings running onto the property.

Plans call for a building of waterproof reinforced concrete up to an elevation above any possible flood stage of the Saginaw River. Above that the building will be steel supported brick structure. There will be stub steel stacks, one on each boiler. Coal will be dumped through a track hopper into an automatic vertical skip hoist, which will discharge through crushing and weighing apparatus on to a shuttle belt conveyor, which travels on a truck over steel plate bunkers. Excess coal will be spouted by gravity from skip hoist tower back to the yard and spread out onto storage by a drag scraper.

Electricity will be generated at 12,000 and stepped up to 24,000 v. by means of auto transformers, one of which will be connected directly to each turbo generator. Part of the current will be transmitted at 24,000 v. into Saginaw and Bay City and the balance of the current

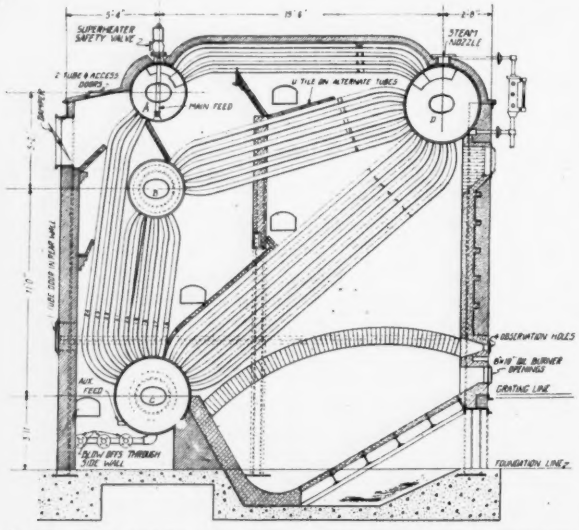
will be stepped up to 140,000 v. into main transmission line, which connects the Au Sable River dams with Flint, Lansing, Battle Creek, Grand Rapids and most of the other large cities of Michigan.

Practically all of the equipment and material has been purchased for the construction of the plant. Construction work is progressing favorably and on schedule in spite of the bad weather experienced this spring.

This station is being designed and constructed under the supervision of the engineering department of the Consumers Power Co. at Jackson, Mich., and the information in this article is presented through the courtesy of H. F. Eddy, mechanical engineer.

High Superheat from New Type Boiler

TESTS AT the main water works station at New Orleans have shown that a superheat of 100 deg. F. can be obtained from the built-in superheater of a new water-tube boiler known as the Adams type, built by the



ADAMS TYPE BOILER AND SETTING INSTALLED BY SEWERAGE AND WATER BOARD OF NEW ORLEANS

Lasker Iron Works, of Chicago. This boiler is of the four-drum bent tube type and is novel in that both an economizer section and a superheater section are built integral with the boiler proper. The illustration shows the general drum and tube arrangement; the setting is that adopted for the New Orleans water works installation.

Drum A serves as the upper drum of the economizer section; feed water enters this drum and passes downward against the gas flow through the three banks of tubes 22, 23 and 24 to drum C in which is provided an auxiliary feed. The steam disengaging area is provided in drum D; drum B forms a link in the path of water circulation.

Probably the most interesting feature of this boiler is the construction of the superheater and the method employed to keep the steam in the path of the gases for a sufficient length of time to obtain a satisfactory superheat. Header boxes are provided in drums A and D opposite the tube ends of the superheater section which consists of tube banks S1, S2, S3 and SK. The SK tubes are 3¼ in. in diameter, which is the same size as the tubes used in the boiler proper and the economizer section. Tubes S1, S2 and S3 are 2 in. in diameter. The steam path through the superheater is as follows:

RESULTS OF TESTS ON ADAMS TYPE BOILER AT MAIN WATER WORKS STATION, NEW ORLEANS

TYPE OF BOILER (Lasker Iron Wks., Chicago)	Adams Water Tube	Adams Water Tube	
	Oil Fired	Oil Fired	
Kind of Furnace:			
Water Heating Surface.....Sq. Ft.	8,620	8,620	8,620
Superheating Surface.....Sq. Ft.	935	935	935
Volume of Combustion Space.Cu. Ft.	1,968	1,968	1,968
Date of Test.....	Apr. 2, 23	April 4, 1923	
Duration.....	4 Hrs.	3 Hrs.	
Boiler No.....	10	9 & 10	
Kind of Fuel.....	Mex. Crude	Mex. Crude	
Steam Pressure by Gage (Corrected).....Lbs. Sq. In.	157.94	168.56	170.24
Temperature of Steam.....F.°	468.6	476.73	461.70
Degrees Superheat.....F.°	98.9	102.2	86.4
Temp. of Feed Water.....F.°	58.8	60	
Temp. of Gases Leaving Boiler...F.°	528.5	474.2	488.8
Draft on Boiler at Damper..In. Water	.62	.317	.33
Draft in Furnace.....In. Water	.06	.....	.....
Temp. of Oil to Burners.....F.°	257	232	
Temp. of Outside Air.....F.°	78	83	
Total inches Fuel Oil, Displacement Measurement.....F.°	101⅝"	124.83	
Temp. of Oil in Fuel Tank.....F.°	151	153	
Pounds per inch at Observed Temp.....Lbs.	136.54	136.44	
Total Pounds Fuel Oil.....Lbs.	13,867	17,032	
Pounds Fuel Oil per hour.....Lbs.	3,467	5,677.3	
Total Pounds Water Fed to Boilers.....Lbs.	166,025	208,775	
Factor of Evaporation.....	1.263	1.261	
Total Equivalent Evap. from and at 212°F.....Lbs.	209,689	263,265	
Equivalent Evaporation from and at 212° F. Per Hr.....Lbs.	52,422	87,755	
Boiler Horse Power Developed.....	1,520	2,542	
Rated Boiler H. P.....	850	1,700	
Percentage of Rated Capacity Developed.....	178.8	149.5	
Equivalent Evap. from and at 212° Per Lb. Fuel.....	15.12	15.46	
Calorific Value 1 Pound Fuel Oil.....B. T. U.	18,200	18,200	
Efficiency of Boiler and Furnace..%	80.7	82.5	
Carbon Dioxide in Flue Gases....%	12.68	12.53	14.00
Number of Burners.....	7	7	7
Type of Burners (A. M. Lockett Co., N. O.) Steam Atomized, Outside Mix.			

No Allowance Has Been Made For Steam Used For Oil Burners.

steam from the drum D passes to drum A through the center tubes in row SK and returns to header box compartments in drum D through the six outer SK tubes on each side. These header box compartments connect with the end groups of S1, S2 and S3 tubes through which the steam is returned to header box compartments in drum A. These latter compartments are arranged to cover the next group of 2-in. tubes so that the steam is returned to corresponding compartments in the front drum. The steam makes four passes through the 2-in. tubes and is finally discharged through the steam nozzle which is secured to the front drum but is connected to the center header box compartment at the end of the fourth pass through the 2-in. tubes. An extension to the header box in drum A allows the superheater safety valve to be directly connected to this drum. The header

boxes extend the full length of the drums and are partitioned so as to give the required number of passes for the steam through the superheater tubes.

Results of tests of the New Orleans water works installation are shown in the table. With Mexican crude oil of 18,200 B.t.u. and feed water at 60 deg. F., an overall efficiency of 82.5 per cent was obtained. The superheat ranged from 86.4 to 102.2 deg. F. and the flue gas reached the temperature of 528.4 deg. F. at 178.8 per cent of boiler rating. These tests were under the supervision of A. B. Wood and S. G. Frank Hass.

Individual Suspension Facilitates Removal of Blocks

IN A new type flat suspended sectional furnace arch recently put on the market by McLeod & Henry Co., of Troy, N. Y., any single block can be removed from underneath or above, without disturbing any other block or the suspension. Reference to the illustrations show that the blocks in the flat part of the arch are of one standard size, interchangeable and suspended in parallel rows from the lower flanges of I beams, each block having its own hook and rocking link.

This suspension is quite flexible, each block hanging straight downward without imposing side thrust upon its neighbors, and each block being free to move laterally in any direction. With all blocks assembled, the mass as a whole can move sidewise in any direction to compensate perfectly for internal expansion, which is made

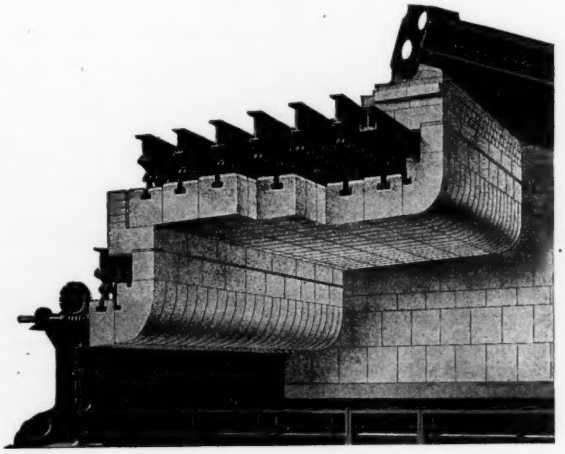


FIG. 1. GAS-TIGHT ASBESTOS WOOL CUSHIONS AT JUNCTION OF ARCH AND BOILER WALLS ALLOW FOR INTERNAL EXPANSION

entirely independent of that of the boiler walls by gas-tight asbestos wool cushions at all junctures of the arch proper with the other boiler parts.

In the case of arches set on a slope, flat bottom surface with straight downward suspension is maintained by beveling the bottoms of the blocks to correspond with the slope, and by proper adjustment of the up-and-down position of the block. The latter is accomplished by the use of different thicknesses of bearing plates to give different heights to the supporting beams.

As shown in Fig. 2, the method of removing and replacing a block from underneath is based upon gravity, acting through a rolling contact between the bottoms of the link and the groove in the block and tending to bring the link back into normal (vertical) position of equilibrium. The various operations are shown in the detail illustration. The blocks are also readily removable from above by grasping the rocking link and pulling the trunnion clear of the hook.

Hanger beams rest permanently upon bearing plates embedded in and distributing the weight downward only on the side walls of the boiler. This is entirely practical as no open end is required to slide out the blocks, as would be necessary if a whole row of blocks rested upon a single fitting. A suitable contour at the back end of

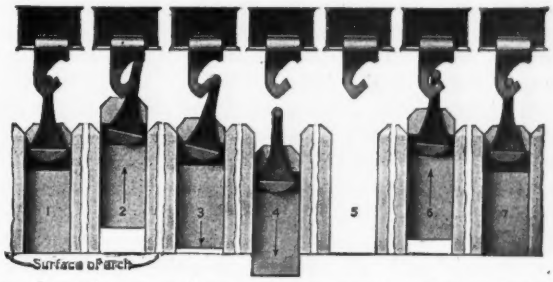


FIG. 2. BLOCKS MAY BE REMOVED FROM ABOVE OR BELOW THE ARCH

the arch to facilitate proper travel of the gases is provided by special end blocks and suspensions which are so arranged that they do not interfere with wall construction above, yet permit perfect ease of removal independent of individual blocks. A similar arrangement is adopted for the auxiliary front arch in automatic-stoker-fired furnaces demanding a high main arch.

Flexibility of all features in the design of this arch permit of ready adaptation to any type of water tube boiler, fuel, draft, and any method of firing. Possible variations in arrangement, position and size of parts make this arch also suitable for metallurgical furnaces, ovens, kilns, and other such uses.

120,000-Hp. Hydro Plant to Feed Energy to Montreal

THERE are a number of features of unusual interest connected with the new St. Maurice power project of the Shawinigan Water & Power Co., of Montreal, Canada. A contract for the hydraulic machinery and equipment for this plant has just been awarded to the Dominion Engineering Works, Limited, of Montreal, Canadian licensees of the William Cramp & Son Ship- & Engine Building Co.

There are to be four 30,000-hp. propeller-type turbines, to be built according to the latest designs developed by the I. P. Morris Department of the Cramp Co. They will, consequently, be the largest turbines of this type in the world, exceeding in unit capacity those recently completed by the Dominion Engineering Works for the Manitoba Power Co. at Winnipeg.

As the contract calls for 120,000 hp., it is also one of the largest orders for power machinery ever placed at one time in Canada, and the new station, when completed, will give the Shawinigan company, from its three plants on the St. Maurice river, a total of over half a

million horsepower for distribution over its high-tension lines to Montreal and vicinity.

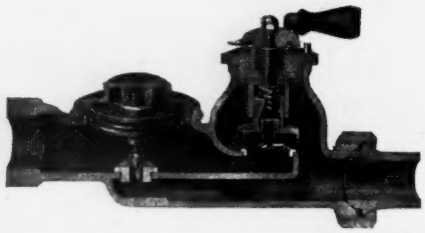
Gres Falls is to be the location of the new station; about 10 mi. below the Shawinigan station, and as far again below Laurentide. The site has been owned by the Shawinigan company for some time. A new subsidiary company, to be known as the St. Maurice Power Co., has been organized to construct and operate the new station, which will be known as the St. Maurice plant. The entire development is being financed by Aldred & Co., of New York.

Construction work on the dam and foundations is already under way, under the immediate supervision of Vice-President Julian Smith of the Shawinigan Water & Power Co. Mr. Smith has promised that the entire plant will be ready in June, 1924, and if this schedule is carried out it will make a record for speedy construction for plants of this size.

Turbines are to operate under a normal head of 60 ft., and to run at a speed of 130 r.p.m. Their performance will be watched with much interest by engineers, as they are to embody a number of improvements recently developed. Among the most interesting of these new features will be the Moody diagonal-flow, propeller-type runner, and the Moody spreading draft tubes, which recently underwent an exhaustive and highly successful series of experimental tests in the I. P. Morris laboratories. All the auxiliary equipment, such as governors, etc., will be manufactured from I. P. Morris designs. The electrical equipment will be furnished by Westinghouse.

Double Service Valve Used to Drain Down-Feed Risers

IN buildings of only one story and in other instances, it is common practice to run the steam supply line along the ceiling of the first floor to feed each radiator or coil through a short down-feed riser which must be



THERMOSTATIC VALVE OPENS IF THERE IS WATER OR AIR IN THE RISER

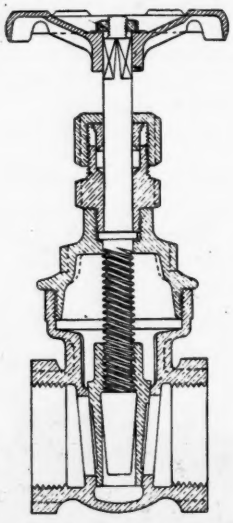
dripped into the return line. This multiplicity of unsightly connections is simplified by the use of a valve brought out by Warren Webster & Co. of Camden, N. J. This valve performs "double service" as a supply valve for the radiator and as a trap for draining the riser. Where there is water or air in the riser, the thermostatically controlled valve is open, permitting the condensate to flow through a bypass in the valve body into the radiator and thence to waste. In the presence of steam, the thermostatic member expands, closes the valve, and thus prevents waste of steam.

Steam is admitted to the radiator in the amount desired, by means of the quick-opening valve, which is provided with a graduated dial and handle. This is not a modulation valve, as the valve disc is designed for the special feature of quick opening without respect to modulating effect.

The thermostatic member is built up of four discs of phosphor bronze and filled with a volatile fluid. The inlet valve is provided with a ring seat and Jenkins disc, to insure tight closing. Its quick-opening feature is provided by a screw stem of such pitch that the valve will be completely opened with les than a complete turn of handle.

Bronze Gate Valve for 150-Lb. Pressure

IN LINE with rising steam pressures and superheats which is a growing practice in modern power plants, the Wm. Powell Co. has just brought out a bronze gate valve which has a reinforced body designed for steam



SOLID WEDGE DISC RISES TO SEAT IN BONNET PERMITTING PACKING UNDER PRESSURE

lines carrying 150-lb. pressure. The disc is of the solid type tapered to fit the seats and the stem is non-rising. The design is such as to permit packing the gland when the valve is under pressure and wide open. Both screw and flange ends are made in sizes up to 3 in.

Co-Operative Plant Scheme for Massachusetts

GOVERNOR Cox, of Massachusetts, signed a bill on April 18 allowing electric light companies to own stock in other companies formed for the purpose of generating large amounts of power. This bill will permit two or more electric companies to unite in building super-power stations which can be located on tidewater and supply the individual companies with large blocks of power at the lowest possible rates. The large co-operative stations will, it is expected, realize great economy, both in fuel cost and in general operating costs, and the signing of the bill by Governor Cox, making possible such stations and interconnecting transmission lines, marks the be-

ginning of the establishment of superpower zones in New England.

Local electric light companies of Fall River, Mass., Brockton, Mass., and Pawtucket, R. I., will unite and build the first of these power plants, to be located at Fall River and to furnish power over 29 mi. of transmission line to Brockton and 15 mi. of line to Pawtucket. The initial expenditure will be about $5,500,000 and Stone & Webster, Inc., of Boston, will handle the design and construction of the station and transmission lines. The first unit of 30,000 kw. capacity will be in operation in 1924 and a second unit will be added soon afterward. The design of the plant permits an ultimate capacity of 200,000 kw.

N. E. L. A. to Hold 46th Convention in New York City

PLANS for the forthcoming 46th Convention of the National Electric Light Association, which is to be held in New York City on June 4 to 8 inclusive with headquarters at the Hotel Commodore, call for a varied program of general and specialized sessions. The former will occupy the morning hours on the last four days of the meeting, while the latter will take place on the afternoons of the first four days, with simultaneous sessions of the four National Sections devoted respectively to accounts, commerce, public relations, and technical developments. There will also be a Public Policy Committee session on the evening of June 7, at Carnegie Hall, and a Customer Ownership Committee session on the afternoon of the same day.

Two of the general sessions will deal with matters of special or general interest to power plant men. On Tuesday, June 5, R. F. Schuchardt, electrical engineer of the Commonwealth Edison Co. of Chicago and chairman of the Technical National Section, will present the report of that section. On Thursday morning, M. S. Sloan, vice-president and general manager of the Brooklyn Edison Co., as chairman of the Electrical Resources of the Nation Committee, will present its report. At the same session, the report of the co-operative work being done by the joint Inductive Co-ordination Committee of the N. E. L. A. and the A. T. & T. will be presented by a member, R. F. Peck, vice-president in charge of operation of the Northern States Power Co. with headquarters at Minneapolis.

IN HANDLING the afternoon sessions under the Technical National Section, a departure from previous practice will be made in assigning a general subject for each session. The presentation of reports on each subject will be followed by a symposium, with speakers selected for their familiarity with certain phases of the subject, and general discussion will be reserved for the close of the meeting. The general subjects of these four sessions are given below, with reports to be given in abstract by the chairmen of the respective committees:

June 4. Problems of Electrical Generation, with reports of the Prime Movers Committee and the Hydraulic Power Committee, and the Generating Station portion of the report of the Electrical Apparatus Committee.

June 5. Conversion and Metering, with Substation portion of the report of the Electrical Apparatus Committee, a report on the Present Status of Safety Code, by Thos. Sproule of the Public Service Corporation of New Jersey, and the report of the Meter Committee. The election of officers for the section will also take place at this meeting.

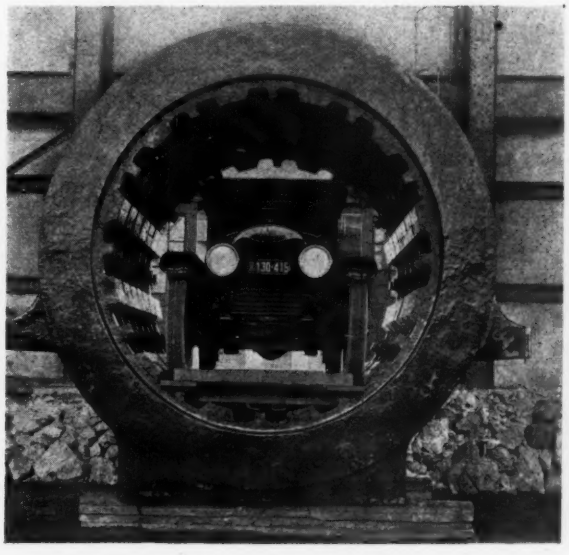
June 6. Problems of Transmission and Distribution and Problems of Utilization, with reports of the Overhead Systems Committee and the Underground Systems Committee, and Motor Rules and Service Voltage portion of the report of the Electrical Apparatus Committee.

June 7. Co-operation on Inductive Co-ordination. This will follow the presentation of the committee report on the subject in the morning. A typical hypothetical case of interference between a power system and a telephone system will be presented and worked out.

SPECIAL TRANSPORTATION ARRANGEMENTS

TRANSPORTATION arrangements are in the hands of Godfrey H. Atkin, 713 Marquette Bldg., Chicago, who is master of transportation. For the convenience of delegates from western points two special trains will leave Chicago at 10:30 a.m., Sunday, June 3. One train, known as the "Blue Special," will run over the New York Central Railroad, and the other, the "Red Special," will run over the Pennsylvania lines. Special Pullmans from Denver, Minneapolis and Kansas City will be attached to the "Red Special," and special sleepers from Detroit and Cleveland will be attached to the "Blue Special." A rate of one and one-half fares for the round trip has been granted to all delegates. This rate will apply to all parts of the country.

Ford Developing Huge Turbine



IN AN ADDRESS before the Western Society of Engineers in Chicago on April 30, on the River Rouge plant of the Ford Motor Co., F. R. Breedlove exhibited the accompanying picture showing one of the first experimental castings of a single drum steam turbo-generator now being developed by the Ford research department for use in the River Rouge plant. Just what the capacity of the machine will be was not stated definitely but it has been rumored that it would reach 150,000 kw. Its size is compared here with a Lincoln automobile.

Boston Company to Use 1200-lb Steam Pressure

IT HAS been announced that a 1200-lb. boiler and generating unit will be installed in the new Weymouth power station of the Edison Electric Illuminating Co. of Boston. This station, which will be located on Weymouth Fore River about 8 mi. from the Edison Company's present "L" Street station, is under the supervision of I. E. Moultrop of the Edison Co., and Stone & Webster, Inc., of Boston, Mass., has been engaged to design and build the plant.

Main generating equipment of the initial installation includes two units to operate at 350-lb. pressure, each having a steam maximum rating of 32,000 kw. and each direct connected to a generator of 30,000-kw. capacity and to an auxiliary generator of 2000 kw. for station auxiliary service. Contract has been placed with the General Electric Co. for these units.

The initial high pressure installation will include a 1200-lb. boiler and a generating unit of 2,000 kw., which will exhaust through a resuperheater into the steam mains supplying the main generating units. The steam temperature for both the high pressure and the main generating units will be 700 deg. F.

Four boilers will be built by the Babcock & Wilcox Company, one to operate at 1200 lb. pressure and three at 375 lb. pressure. High pressure economizers will be installed in all four. It is planned that additional high pressure boilers and units will be installed later (after the many new problems in station design introduced by the use of the 1200-lb. pressure have been worked out), so that three of the high pressure units exhausting at 375 lb. will furnish enough steam for one main generating unit.

News Notes

CANADIAN INGERSOLL-RAND CO., Limited, 260 St. James St., Montreal, is placing on the Canadian market a complete line of straight line and duplex ammonia compressors for steam, belt, electric motor or oil engine drive. These machines correspond with those manufactured in this country by the Ingersoll-Rand Co., New York. The Canadian Ingersoll-Rand Co. has been building air and gas compressors of all types for 33 yr. and has well equipped plants for this purpose as well as a chain of sales and service branches from coast to coast.

DWIGHT P. ROBINSON & CO. has started work on the design and construction of a complete new switching plant to replace and extend the present facilities of the Narragansett Electric Lighting Co. of Providence, R. I. The work includes a new four-story brick and concrete building and a smaller three-story extension to the present switch-house. These buildings will house complete new switching equipment and switchboard. The company at present generates about two-thirds of its current and obtains the other third from the New England Power Co. over 60,000-v. lines. All power will be distributed from the new switching station to substations at 11,000 and 22,000 v. In order to provide for future expansion, all equipment will be designed for 22,000 v.

CONTROLLING interest in the Crandall Packing Co. of Palmyra, New York, has been purchased by Olin J. Garlock, founder of the Garlock Packing Co., of the same city. The Crandall Packing Co. has been controlled for some years by Dr. Hennessy, of Palmyra, and his estate. This purchase combines two of the strongest of the packing companies under the leadership of a man who has been identified for many years with the industry.

METROPOLITAN POWER CO. is being incorporated under the laws of Pennsylvania to build and operate a large steam-electric power generating plant at Middletown, Pa., on the Susquehanna River. All of the power generated will be sold to the Metropolitan Edison Co. and used to meet the demand for electric power service in the extensive industrial district of Reading, Lebanon and sections in the vicinity of Middletown and Steelton. It is expected the new plant will begin generating current not later than the summer of 1924. The new plant will be linked up with the hydroelectric power station of the York Haven Water & Power Co. and the Reading plant of the Metropolitan Edison Co.

WALTER GOODENOUGH has joined the staff of Dwight P. Robinson & Co., Inc., and will take part in the various activities of that company.

PAUL W. LAWTHER has just been made sales manager of the S. F. Bowser & Co., of Texas, according to an announcement made by T. D. Kingsley, sales manager of the parent company at Fort Wayne.

LIPTAK FIRE-BRICK ARCH CO., of Chicago, manufacturer of Liptak double Suspension arches and the Liptak interlocking fire brick wall, has recently secured the services of C. R. Matheny, who will act as District Manager, with offices at 50 Church St., New York City. Mr. Matheny was formerly General Manager of the Republic Flow Meters Co., of Chicago.

SCHUYLER S. WHEELER, president of the Crocker-Wheeler Co., Ampere, N. J., died in his home at 755 Park Ave., New York, on April 20, aged 63 yr. He was born in New York and early joined the engineering staff of Thomas A. Edison, having had charge of the first Edison station begun in 1883. Between that time and 1888, when he organized the Crocker-Wheeler Co., Mr. Wheeler was active in several electrical companies and perfected a number of important inventions.

MCCLAVE-BROOKS CO. announces the opening of a branch office in St. Louis, Mo. William C. Smith is manager of the new office, which is located at 276 Arcade Building, and will look after the interests of the company's customers in Eastern Missouri and Southern Illinois. It is also announced that the Harvill Supply Co., 315 Chamber of Commerce Bldg., Nashville, Tenn., has been appointed to represent the McClave-Brooks Co. in that city.

JOHN GILBERT WARD, for 30 yr. treasurer of the Babcock & Wilcox Co., died at his residence, Glen Ridge, N. J., on April 22. Mr. Ward was born in Cuba on July 12, 1854, where his father, who was an Englishman, had settled for a time. His mother was a Cuban. He came to the United States with his parents early in life and his boyhood was passed in Delaware. Mr. Ward devoted the greater part of his life to the Babcock & Wilcox Co., with which he became connected in 1888 as a clerk in the treasurer's office. In 1893 he was elected treasurer and a director of the company, both of which offices he held continuously until the time of his death.

GIFFORD-WOOD CO., Hudson, N. Y., has changed the location of its Buffalo office to Pittsburgh, Pa., and after May 1 will be located in the Peoples Bank Bldg., corner Fourth Ave and Wood St.

S. P. WRIGHT & CO., district representative of the Conveyors Corporation of America for Montana, has moved its offices from 109 East Broadway, Butte, Mont., to 812 East Iron St.

GENERAL ELECTRIC CO. has just received a contract for a 60,000-kw. cross compound steam turbine generator from the Commonwealth Edison Co., of Chicago, Ill. This is the largest unit ever purchased by that company and will be installed in the new Crawford Ave. central station. The ultimate capacity of the station will be from 500,000 to 600,000 kw.

SANFORD RILEY STOKER CO., Worcester, Mass., and the Ground Coal Engineering Co., formerly of Chicago, Ill., announces the formation of a corporation for the manufacture and installation of pulverized coal apparatus to be known as the Ground Coal Engineering Corporation with headquarters at Worcester, Mass. R. Sanford Riley, who is also president of the Riley Stoker Co., is president of the new corporation and M. W. Arrowood is vice president and executive engineer.

CENTRAL MAINE POWER CO. has under consideration a plan to supply Knox County with uninterrupted electric service by building a new power station at Union.

Plans have been made, options taken on the land, borings made and the undertaking authorized by the directors of the company. Little remains now save the financing in order to bring the project to the stage when work will start. The financing will be done in the territory which will be benefited by the development.

Present plans call for a dam at the foot of Kennebec Lake in the town of Union. This will be an earth dam, 40 ft. high, which will give a head of 65 ft. for this development. From the dam a 900-ft. penstock will carry the water to a power station where a single unit will turn out 3500 hp.

SUSQUEHANNA POWER CO. has filed an application with the Federal Power Commission for a preliminary permit for a power project in the Susquehanna River located at a point between the head of tidewater and the town of Conowingo, Maryland. There are five possible dam sites in this stretch of the river and investigations are being made to determine which is the most satisfactory location. The company contemplates the construction of a dam about 90 ft. high, creating slackwater to the Holtwood power plant at McCall's Ferry in Lancaster and York counties, Pennsylvania. The project will develop 360,000 hp. It will serve the territory within a radius of approximately 100 mi. of its power plant. This would make the power available for Washington, Philadelphia, Baltimore, Trenton and Wilmington.

KNOXVILLE POWER & LIGHT CO. has applied to the Federal Power Commission for a preliminary permit for a series of four projects on the Clinch River, in Roan, Loudon, Anderson, Knox, Union, Campbell, Grainger, Claiborne and Hancock counties, Tennessee, and in Scott and Lee counties, Virginia. Operations on the upper Clinch site call for a dam 180 ft. high, storing 800,000-acre ft. of water, and developing 53,000 hp. At the middle Clinch site a dam 175 ft. high will be built, storing 1,025,000-acre ft. of water and developing 85,000 hp. The project at the lower Clinch site provides for a dam 85 ft. high, storing 625,000-acre ft. of water and developing 46,000 hp. At the Clinton site a dam 35 ft. high will be built, designed to develop 17,000 hp. The power will be used in the existing system of the company to meet the expected growth of the load. This application conflicts with an application previously received from the Tennessee Hydro-Electric Co.

ALABAMA POWER CO. filed formal petition with the Alabama Public Service Commission recently for a certificate of convenience and necessity, which would permit the construction of a dam at lock 17 on the Warrior River.

WORK IS NOW under way for the installation of a new 15,000-kw. generating unit in the present electric generating plant of the Memphis St. Railway Co. This plant is about to be acquired by the Memphis Power & Light Co.

GENERAL BUILDING activity among public utilities is indicated by the fact that Stone & Webster now has under design and construction steam power station and transmission line work amounting to $35,000,000 and is also doing hydroelectric development work and other building amounting to as much more.

B. C. EDGAR, vice-president of the Tennessee Electric Power Co., has announced that directors of the company have authorized the expenditure of $1,800,000 in further development of the hydro-electric plant at Great Falls. This development will more than double the horsepower. The plans call for raising the dam on Caney Fork 35 ft.

Books and Catalogs

STEAM TURBINE PRINCIPLES AND PRACTICE by Terrell Croft. First edition; 5½ by 8¼ in., cloth, 348 pages, 282 illustrations; New York, 1923.

A new book on steam turbines, written for the practical man who wishes to obtain a sound working knowledge of steam turbines and the principles of turbine operation. It has been written to provide the operating engineer, the plant superintendent or manager with such steam-turbine information as he requires in his everyday work. The aim has been to treat only topics of two general classes: (1) Those with which a man must be familiar to insure the successful and economical operation of steam turbines. (2) Those a knowledge of which is necessary to enable a man—one who is not familiar with the details of its design or theory—to make a wise choice if he contemplates the purchase of a turbine. Only sufficient theory is given to insure a sound understanding of the principles of turbine operation. The "design" of turbines is not treated at all. A working knowledge of arithmetic will enable one to read the book intelligently.

In examining the book one is struck with the excellent character of the illustrations. Drawings for nearly all of the illustrations were made especially for the work and the pictures are so presented that they convey the desired information with a minimum of supplementary discussion.

THE "MECHANICAL WORLD" Electrical Pocket Book, 1923; 389 pages, 117 illustrations, 6¼ by 4 in., cloth; Manchester, England.

This little book is a companion volume to the Mechanical World Year Book and like its bigger brother contains much information of value to the engineer. Prominent among the new features of the present issue of this handbook is a newly-written section on Electrical Measuring Instruments, which describes the principal devices used in this connection and embodies a number of new illustrations. Other minor additions have been made in several of the more permanent sections and the book revised generally.

STEAM POWER, by C. F. Hirshfeld and T. C. Ulbricht. Second edition revised and enlarged; 474 pages, 252 figures: 5¼ by 7½, cloth; New York, 1922.

In elementary text-book style, this book covers the essential theory and practice as applied to steam engines, turbines, boilers and their accessories. It has been prepared with a great many well chosen illustrations. The text is clearly written and augmented with illustrative problems. Based on each chapter is a set of problems which will be found of value in fixing in the student's mind the principles set forth in the text. Chapter headings are: physical conceptions and units, the heat power plant, the ideal steam engine, entropy diagram, temperature entropy diagrams of steam cycles, the real steam engine, the indicator diagram and derived values, compounding, the D slide valve, Corliss and other high efficiency engines, regulation, the steam turbine, condensers and related apparatus, combustion, fuels, steam boilers, recovery of waste heat, boiler feed pumps and other auxiliaries, performance of steam power equipment.

SAFE PRACTICES, Pamphlet No. 54, entitled "Handling Material," has just been published by the National Safety Council, 168 North Michigan Ave., Chicago.

Handling material is recognized as one of the greatest safety problems in industry and, according to state reports, handling material by hand causes more accidents than all machinery. The pamphlet is divided into the following main divisions: Power Trucks, Hand Trucks, Piling Material, Handling by Hand and Safe Habits of Work, each of which is again subdivided into paragraphs dealing with the different types of equipment used and the different methods employed in handling various types of material. The pamphlet is freely illustrated with photographs and diagrams. A large number of industries are covered and owing to the fact that handling material is common to every industry, the pamphlet has an unusually wide range of usefulness.

USE OF STEAM turbines for driving heavy machinery exposed to carbon dust and grit is advocated in a pamphlet issued by the De Laval Steam Turbine Co., Trenton, N. J. Two steam turbines were recently installed in the by-products coke oven plant of the New England Fuel & Transportation Co., at Everett, Mass., for driving direct current generators and for operating swing hammer coal crushers. These turbines run at 5000 r.p.m., which is reduced to 750 r.p.m. for the crushers by a double helical speed reducing gear. The use of turbines for driving the crushers has not only effected considerable savings in plant investment as compared with motor drive, but also makes it possible to keep the crushers in operation when the main power units are shut down. The lubricating oil for the entire plant is protected by centrifugal purifiers.

CONSIDERABLE INFORMATION is presented in two booklets, one on trade marks and the other on patents which have been issued by Richards & Geier, patent and trade mark attorneys of New York City.

PENFLEX ALL METAL heavy duty hose and couplings for tank car unloading are described in Bulletin No. 55B, which has been issued by the Pennsylvania Flexible Metallic Tubing Co., of Philadelphia, Pa. One of the uses for this hose is the unloading of fuel oil from tank cars or boats.

PREVENTING LEAKS in the use of steam, water, air and oil, is discussed in a folder issued by the Diamond Rubber Co., of Akron, Ohio. Charts are shown which give the amount of steam wasted by leaks of various sizes and for different steam pressures. Elbon packing for various uses is also described.

THERMOLITH, an all temperature fire cement, is described in a folder now being distributed by the Harbison-Walker Refractories Co., of Pittsburgh, Pa. Thermolith is a cement that forms a bond at atmospheric temperatures and, according to the bulletin, will remain firm under the highest temperatures used under even extreme furnace conditions. The importance of a perfect bond for fire brick is pointed out and the uses of Thermolith are presented.

ACCURACY OF 0.1 in 60 sec. is attained in a portable timing device, described in Bulletin No. 46,053, recently published by the General Electric Co.

This device consists of an encased clock, to be used with a standardized clock as a means of secondary timing, to supplant the stop watch.

The portable timing device has applications which enable its use with graphic instruments, measurements of angular velocities, and for indicating a definite time-interval ranging from one second to any whole number of minutes.

WATSON MULTI-SPEED motors are described in a bulletin published by the Louis-Allis Co., of Milwaukee, Wis. These multi-speed alternating current motors are nothing more than a squirrel cage motor with two or more stator windings. These windings are independent of each other and each winding develops a different speed. A drum control or switch applies current of two end windings and the motor becomes a constant speed squirrel cage motor, operating at the required speed. Illustrations are presented, showing the application of these variable speed motors to various uses, and the design details are discussed.

PUMPING AND WATER distributing systems of the Lindsay-Strathmore irrigation project in Tulare County, Calif., is described in a well illustrated leaflet issued by the De Laval Steam Turbine Co., of Trenton, N. J. This district is an irregular tract on the foothills of the San Joaquin Valley, 62 miles south of Fresno, and contains 15,500 acres, of which 8000 are planted with oranges and lemons. The water supply is obtained by pumping from wells in the delta of the Kaweah River, and is lifted to the high level flumes and pipe lines by large centrifugal pumps driven by electric motors receiving power from a long-distance transmission line.

Sparks from the Advertising Pages

Where Buyers and Sellers Meet

Business Building Impressions

High over the business district of a large city a man in an aeroplane spelled out in white smoke against the clouds the name of a popular brand of cigarettes.

Under the shifting sands of 30 centuries were found the inscriptions of a long-forgotten monarch.

Each strove to make impressions on the minds of men and each chose his medium according to his lights.

The smoke fading on the breeze left an impression as momentary as the smoke curling from the cigarette it advertised. The crude pictures carved on stone were buried by the sands and came to light only after many civilizations had fallen, been forgotten and new ones had risen in their stead.

Today more than ever before impressions decide the fate of men and their works, determining what shall increase and be perpetuated and what shall be torn down and replaced.

On the art and science of making mental impressions all other arts and sciences depend. With the growth of one the others grow and on the records of the past future advances are made.

What factors decide the success of this all-controlling force of impressions?

Serviceability for one—the power to help other men.

Wonderful as that ancient tomb may be 3000 years elapsed before it came to the attention of the modern world, and then it carried no message of use to us today nor did it help the affairs of the man who caused it to be built.

On the other hand, the diversion of water to promote the growth of crops, an idea in use before this tomb was built, survived and was passed on and is today commemorated in irrigation works greater than a thousand tombs.

Given a serviceable idea, one that has inherent power to help men, the next factor which determines its success is the timeliness of its presentation.

The man in the aeroplane chose the noon hour in which to write on the sky—the time when the streets were crowded and men were thinking about their after lunch smoke and had time to buy. If he had flown at midnight, though he had written in letters of flame, he would have lost much of the transient impression he did make.

With service right and the time right there still remains the most important factor—the medium of presentation. Smoke will remind people of smoke. Tombs remind people that some one died and, by implication, that he once lived.

Men with more than ephemeral propositions do not use smoke as a means to present them. Men with live, ready-to-use ideas do not engrave them on the walls of tombs.

Somewhere between the extremes is the time, the place and the means where impression-power may be generated most effectively and economically per unit developed for any particular idea or service.

Machines, equipment and supplies are only a combination of ideas and service made into complete, ready-to-use products.

Advertising them is the great modern way of making impressions that increase the sale of these products and reduce the cost of selling—that increase production and lower its cost—that put them in service and add to the service they give.

Leading manufacturers of machinery, equipment and supplies use the pages of POWER PLANT ENGINEERING because they have products that are the highest developments of serviceability to the power plant.

They select POWER PLANT ENGINEERING to present them because it goes to its readers at precisely the intervals of time to develop the most impression-power at the least cost—sufficiently often to keep them abreast of their profession, but not too often to preclude a thorough reading.

They have found that these pages are the place where leading power plant men look both for the ways and means to build better plants and to operate them more economically.

As a result of the same keen analysis that has enabled them to build products that improve service and promote economy in the power plant, they have selected POWER PLANT ENGINEERING as the medium to most economically build their business, thereby to hold their leadership in the service and economy they give.

Machinery, Equipment and Supplies Used In The Production and Transmission of Power

Under the heading of each product listed will be found the names of the manufacturers of that product. The index to advertisers, next to the back cover, gives the page numbers on which the manufacturers' descriptive advertisements appear.

AIR COMPRESSORS.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
American Steam Pump Co., Battle Creek, Mich.
Dean Bros. Co., Indianapolis, Ind.
De Laval Steam Turbine Co., Trenton, N. J.
Gardner Governor Co., Quincy, Ill.
Ingersoll-Rand Co., New York.
Worthington Pump & Machinery Corp., New York, N. Y.
Yeomans Bros. Co., Chicago, Ill.

AIR FILTERS.
Midwest Steel & Supply Co., Inc., New York, N. Y.

AIR WASHERS.
American Blower Co., Detroit, Mich.
Badger & Sons Co., E. B., Boston, Mass.
Cooling Tower Co., Inc., The, New York.
Spray Engineering Co., Boston.

ALARMS, HIGH AND LOW WATER.
Hills-McCanna Co., Chicago, Ill.
Huyette Co., Inc., The Paul B., Philadelphia.
Northern Equipment Co., Erie.
Reliance Gauge Column Co., Cleveland, Ohio.
Williams Gauge Co., The, Pittsburgh, Pa.

ARCHES, BOILER AND COMBUSTION.
American Arch Co., New York.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Detrick Co., M. H., Chicago.
Green Engineering Co., E. Chicago, Ind.
Harbison-Walker Refractories Co., Pittsburgh, Pa.
Jointless Fire Brick Co., Chicago.
Liptak Fire-Brick Arch Co., Chicago, Ill.
McLeod & Henry Co., Troy, N. Y.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., N. Y.

ASH CONVEYING SYSTEMS.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Conveyors Corp. of America, Chicago, Ill.
Detrick Co., M. H., Chicago.
Green Engineering Co., E. Chicago, Ind.
Jeffrey Mfg. Co., The, Columbus, Ohio.
Link-Belt Company, Chicago.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.
Weller Mfg. Co., Chicago, Ill.

BABBITT METAL.
Magnolia Metal Co., N. Y.
Scully Steel & Iron Co., Chicago.

BAROMETERS.
Taylor Instrument Cos., Rochester, N. Y.

BEARING METAL.
Magnolia Metal Co., N. Y.
Strong, Carlisle & Hammond Co., Cleveland, Ohio.

BEARINGS.
National Tube Co., Pittsburgh.

BELT CONVEYORS.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Goodrich Rubber Co., B. F., Akron, Ohio.
Jeffrey Mfg. Co., The, Columbus, O.
Portable Machinery Co., Passaic, N. J.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.
Weller Mfg. Co., Chicago, Ill.

BELT DRESSING.
Cling-Surface Co., Buffalo, N. Y.
Crandall Pkg. Co., Palmyra, N. Y.
Dixon Crucible Co., Jos., Jersey City, N. J.
Stephenson Mfg. Co., Albany, N. Y.

BELTING.
Goodrich Rubber Co., B. F., Akron, Ohio.
New York Belting & Packing Co., New York, N. Y.
Quaker City Rubber Co., Phila.
Voorhees Rubber Mfg. Co., Jersey City, N. J.

BELTING, SILENT CHAIN.
Link-Belt Co., Chicago, Ill.

BELT LACING.
Bristol Co., The, Waterbury, Conn.

BLOWERS, FAN & FURNACE.
Carling Turbine Blower Co., Worcester, Mass.
Coppus Engineering Corp., Worcester, Mass.
De Laval Steam Turbine Co., Trenton, N. J.
Ingersoll-Rand Co., New York.
Perfection Grate & Supply Co., Springfield, Mass.
Sturtevant Co., B. F., Boston.
Terry Steam Turbine Co., Hartford, Conn.
Wing Mfg. Co., L. J., New York.

BLOWERS, PORTABLE ELECTRIC.
Clements Mfg. Co., Chicago, Ill.

BLOWERS, STEAM.
McClave-Brooks Co., Scranton.
Schutte & Koerting Co., Phila.

BLOWERS, TUBE.
Bayer Co., The, St. Louis, Mo.
Diamond Power Specialty Corp., Detroit, Mich.
Marion Mach., Fdry. & Supply Co., Marion, Ind.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.
Sherwood Mfg. Co., Buffalo, N. Y.

BLOWERS, TURBINE.
Carling Turbine Blower Co., Worcester, Mass.
Moore Steam Turbine Corp., Wellsville, N. Y.
Wing Mfg. Co., L. J., New York.

BOILER BAFFLES.
American Arch Co., New York.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Engineer Co., The, New York.
Johns-Manville, Inc., New York.
Jointless Fire Brick Co., Chicago.
King Refractories Co., Inc., Buffalo, N. Y.
Quigley Furnace Specialties Co., Inc., N. Y.

BOILER CAP CLEANERS.
Paragon Power Spec. Co., Hartford, Conn.

BOILER COMPOUND.
Boiler-Kote Co., Chicago, Ill.
Dearborn Chemical Co., Chicago.
Hawk-Eye Compound Co., Blue Island, Ill.
Paige & Jones Chemical Co., Inc., New York.

BOILER COMPOUND FEEDERS.
Hills-McCanna Co., Chicago, Ill.

BOILER COVERING.
Celite Products Co., New York.
Quigley Furnace Specialties Co., Inc., N. Y.

BOILER FEED WATER PURIFYING APPARATUS.
Graver Corp., E. Chicago, Ind.
Griscom-Russell Co., New York.
Paige & Jones Chemical Co., Inc., New York.
Permutit Co., New York, N. Y.

BOILER MOUNTINGS.
Lunkenheimer Co., Cincinnati.

BOILER SETTING CEMENT.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Harbison-Walker Refractories Co., Pittsburgh, Pa.
Huyette Co., Inc., The Paul B., Philadelphia.
Jointless Fire Brick Co., Chicago.
King Refractories Co., Inc., Buffalo, N. Y.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., N. Y.

BOILER SETTINGS.
American Arch Co., New York.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Harbison-Walker Ref. Co., Pittsburgh, Pa.
Jointless Fire Brick Co., Chicago.
King Refractories Co., Inc., Buffalo, N. Y.
McLeod & Henry Co., Troy, N. Y.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., N. Y.

BOILER SKIMMERS.
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BOILERS.
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Badenhausen, Phillips, Phila.
Brownell Co., The, Dayton, O.
Brunswick-Kroeschell Co., New Brunswick, N. J.
Casey-Hedges Co., The, Chattanooga, Tenn.
Connelly Boiler Co., The D., Cleveland, Ohio.
Edge Moor Iron Co., Edge Moor, Del.
Erie City Iron Works, Erie, Pa.
Heine Boiler Co., St. Louis, Mo.
Keeler Co., E., Williamsport, Pa.
Page Boiler Company, Chicago.
Union Iron Wks., Erie, Pa.
Vilter Mfg. Co., Milwaukee, Wis.

BOILER TUBE PROTECTORS.
Cruise & Co., Elizabeth, N. J.

BOILER TUBES.
National Tube Co., Pittsburgh.
Scully Steel & Iron Co., Chicago.

BOILER WALL COATINGS.
Boiler-Kote Co., Chicago, Ill.
Johns-Manville, Inc., New York.

BOOKS AND SCHOOLS.
Hays School of Combustion, Chicago.
McGraw-Hill Book Co., Inc., New York, N. Y.
Stumpf Una-Flow Engine Co., Inc., Syracuse, N. Y.

BRIDGE CRANES,—ORE AND COAL HANDLING.
McMyler-Interstate Co., The, Cleveland, Ohio.

BRUSHES, DYNAMO AND MOTOR.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, GRAPHITE.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, WIRE.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.

BUCKET ELEVATORS.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Link-Belt Company, Chicago.
Webster Mfg. Co., The, Chicago.

BUCKETS, CLAMSHELL.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
McMyler-Interstate Co., The, Cleveland, Ohio.

BUCKETS, ORANGE PEEL.
McMyler-Interstate Co., The, Cleveland, Ohio.

CALORIMETERS, GAS RECORDING.
Precision Instrument Co., Newark, N. J.

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Webster Mfg. Co., The, Chicago.

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CEMENT, ASBESTOS.
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Jointless Fire Brick Co., Chicago.
King Refractories Co., Inc., Buffalo, N. Y.
Quigley Furnace Specialties Co., Inc., N. Y.

CEMENT, IRON.
Smooth-On Mfg. Co., Jersey City, N. J.

CHAINS, DRIVE.
Jeffrey Mfg. Co., The, Columbus, O.
Link-Belt Company, Chicago.

CHAIN WHEELS.
Babbitt Steam Specialty Co., New Bedford, Mass.

CHIMNEYS.
American Chimney Corp., N. Y.

CLEANERS, BOILER TUBE.
General Specialty Co., Buffalo.
Huyette Co., Inc., The Paul B., Philadelphia.
Lagonda Mfg. Co., Springfield, Ohio.
Liberty Mfg. Co., Pittsburgh, Pa.
Pierce Co., The Wm. B., Buffalo.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.
Roto Co., The, Hartford, Conn.
Ruggles & Ruggles, Batavia, Ill.
Scully Steel & Iron Co., Chicago.
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COAL AND ASH-HANDLING MACHINERY.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Conveyors Corp. of America, Chicago, Ill.
Detrick Co., M. H., Chicago.
Fairbanks, Morse & Co., Chicago.
Green Engineering Co., E. Chicago, Ind.
Jeffrey Mfg. Co., The, Columbus, O.
Link-Belt Co., Chicago.
McMyler-Interstate Co., The, Cleveland, Ohio.
Portable Machinery Co., Passaic, N. J.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.
Weller Mfg. Co., Chicago, Ill.

COAL CRUSHERS.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Fuller-Lehigh Co., Fullerton, Pa.
Jeffrey Mfg. Co., The, Columbus, O.
Pennsylvania Crusher Co., Phila.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.
Weller Mfg. Co., Chicago, Ill.

COAL STORAGE EQUIPMENT.
Brown Hoisting Machinery Co., The, Cleveland, Ohio.
Jeffrey Mfg. Co., The, Columbus, O.
Link-Belt Company, Chicago.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.
Weller Mfg. Co., Chicago, Ill.

COAL WEIGHING AND MEASURING EQUIPMENT.
Webster Mfg. Co., The, Chicago.

COCKS, AIR AND STEAM.
Dart Mfg. Co., E. M., Providence, R. I.
Powell Co., Wm., Cincinnati, O.
Williams Valve Co., D. T., Cincinnati, O.

COCKS, BLOWOFF.
Scully Steel & Iron Co., Chicago.
Williams Gauge Co., The, Pittsburgh, Pa.